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EcoWater report

Populated Technology Inventory

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The EcoWater project was conducted by an international consortium coordinated by NTUA (National Technical University of Athens). IVL participated in the R & D work, in addition to leading one of the industrial case studies (Volvo Trucks), represented by Volvo Technology.

EcoWater ran 2011-2014. The project is presented in more detail on http://environ.chemeng.ntua.gr/ecoWater/
The project website holds a complete repository of all public deliverables from the EcoWater project.

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EcoWater

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

Collaborative project, Grant Agreement No: 282882

Deliverable 1.3

Populated Technology Inventory

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Abstract

This report presents the populated technology inventory, i.e. the database compiled after collecting information on the technologies relevant to the EcoWater Case Studies.

In addition to the generic database information, the inventory holds data on technology economic parameters, technology environmental parameters and technology efficiency parameters.

The actual technology inventory is delivered as an Excel workbook, holding one sheet per EcoWater Case Study. Each Case Study worksheet follows the same structure, but they differ in terms of which parameters are considered of importance to the technologies added. This technology inventory (Deliverable 1.3), has been populated with data from the Case Studies.

This report also describes the theory around the water system and innovative technologies researched in the project, as well as the environmental midpoint impact categories used to assess the environmental performance of technologies in the Case Studies.

Contents

1 Introduction

The purpose of EcoWater Task 1.2 *Technology inventory for eco-efficient water systems and use* was to design and populate a data inventory for technologies relevant to the EcoWater Case Studies (CS). The main environmental, cost and efficiency parameters associated with the technologies were included. It is worth noting that the term “efficiency parameter” refers to technology efficiency when used in the context of T1.2. It is different from the eco-efficiency indicators developed in Task 1.1 *Review and selection of eco-efficiency indicators according to Case Study specificities*. However, this report briefly presents the chosen midpoint environmental indicators that are part of the eco-efficiency indicators.

This deliverable is the second of two from T1.2 and it reports on the population of the technology inventory. The deliverable consists of two parts; this document, which describes the parameters used in the inventory, and the actual populated technology inventory (Excel-file).

The populated inventory will serve as a database of technologies to be integrated into the EcoWater tools developed in T5.3 *Development of toolbox for meso-level eco-efficiency of systems/products*.

The Description of work (DoW) states the following: “D1.3) Populated technology inventory: The populated technology inventory (information base) will include structured information on technologies for improving the environmental footprint of water use in agricultural, industrial and urban settings.”(DoW EcoWater)

IVL has edited and compiled this report and the data inventory. Section 3 is jointly compiled by IVL and the NTUA. NTUA is author of Section 4, midpoint indicator description in Annex II, and the literature survey of technologies in Annex III.

2 Description of the technology inventory

2.1 Methodology

A first draft of the inventory template was composed by IVL; taking into account a technology database structure previously used in the European project OPTIMA (OPTIMA website) and the specific needs of the EcoWater project. The technology inventory template was then further developed through discussions in the working group of T1.2.

The group decided that a good way to pinpoint the important technological parameters was to add a few example technologies to the first draft of the template (Deliverable 1.2). Adding example data for those technologies would help specifying the parameters. The members of the working group provided input on example technologies and specific parameters relevant to the EcoWater case study each member is linked to. The Case Study leaders have also been consulted, some of which are not part of the working group of T1.2. Discussions following that exercise helped streamlining the interpretation of parameters across the working group.

During the first three Case Study development phases, several more parameters have been added, and some deleted or renamed.

Input from WP2-WP4 provided info on which technologies to be included, values on the representative data on the inventory parameters and/or help on where to find the sources of information to fill out the inventory with values. The inventory has been populated with data for currently used technologies (for Business As Usual, BAU, scenarios) as well as new technologies.

In particular, information and data was gathered from the work on

- Value chain mapping, in tasks T2.1, T3.1 and T4.1.
- Baseline assessment, in tasks T2.2, T3.2 and T4.2.
- Identification of technologies for eco-efficiency improvements, were done in tasks T2.3, T3.3 and T4.3.

2.2 Inventory structure

The EcoWater technology inventory consists of an Excel workbook holding a front page and subsequently one worksheet per Case Study. The structure of the CS worksheets is the same across cases, although technology economic / environmental / efficiency parameters differ between the CS.

The general format of the CS inventory tables (worksheets) is presented in Table 1. Information on technologies has been entered as records (x) in the rows of the worksheet. Each row holds the information on one registered technology.

Table 1: Generic structure of the technology inventory tables

Common database fields			Technology performance parameters				Technology economic parameters			Technology environmental parameters			Technology efficiency parameters			Additional information
			Group			...	Group		...	Group		...	Group		...	
			Name		...	...	Name	...	...	Name	...	...	Name	...	...	
			Unit		...	...	Unit	...	...	Unit	...	...	Unit	...	...	Narrative
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

2.3 Common database fields

All CS inventory tables start with a set of common database fields with the purpose of setting the context of the recorded data. The fields should be filled in for each technology of the database and the interpretation of those fields is as follows:

- Technology name:

  Descriptive name of the technology, e.g. Disinfection by chlorination.

- Type 1:

  Identification field to indicate if the technology is part of Business As Usual (BAU) or if it is a new technology (T). Each registry shall also include a technology unique serial number, e.g. BAU1, BAU2, T1, T2, etc.

- Type 2:

  Identification field to indicate if the technology is used as substitution for a BAU technology or as an additional technology. The record should show either the Type 1 record for the substitute BAU (e.g. BAU3) or 0 (for technologies used in addition to BAUs).

- Source/Reference:

  The source/reference of the data entered in the inventory for this particular technology, e.g. scientific literature, data from technology supplier.

- Author:

  Name of the person who made the first entry of the technology in the inventory.

- Creation date:

  Date when the technology was added to the inventory.

- Last modification date:

  Date of the latest modification of the records for the technology.

- Modified by:

Name of the person who made the latest modification of the technology in the inventory.

- Short description:

  Text describing the technology. Concise description but more informative than the “Technology name” field.

- Process:

  The record should be the name of the process where the technology is (or can be) applied, e.g. Abstraction by pumping, Water purification.

- Reference unit:

  The technology reference unit for which the subsequent parameter values apply, e.g. one piece of XX equipment with YY capacity, or specific equipment model, if relevant.

- Level of maturity (narrative):

  The level of maturity of the technology is described using the Technology Readiness Level (from experimental level to applied technology which is successfully operating) (DOE, 2011)..

During the development of the inventory, and since submission of D1.2, the field “level of maturity” was added in addition to the original fields.

2.4 Technology parameter groups

After the common database fields follows a couple of technology performance parameters, which do not fall within any of the three parameter categories (economic/environmental/efficiency). Currently listed performance parameters are:

- Technology lifetime
- Reliability

What follow after is, in turn, the technology economic parameters, the technology environmental parameters and the technology efficiency parameters. Since the number of parameters within each category is quite large, they have been clustered into groups for simplification. The parameter groups are:

- For economic parameters
  - Cost
  - Value
- For environmental parameters
  - Emissions to air
  - Water quality influence
  - Water use
  - Resource use
  - Solid waste

    - Background impacts
- For efficiency parameters
    - Energy
    - Physical

The inventory format allows for using groups within the performance parameter category as well.

The last column of the technology inventory template holds a narrative field for additional information. It can be used to record any qualitative information about the technology, such as:

- Complexity of the technology
- Acceptance of technology by stakeholders/actors involved or affected by its actual implementation
- Foreseeable barriers for introduction of technology (cultural, regulatory or other)
- Foreseeable drivers for introduction of technology (cultural, regulatory or other)
- Lessons from previous use of technology in other fields of application.

2.5 Parameter specifications

For practical reasons parameter names used in the technology inventory had to be relatively short. The technology performance, economic, environmental and efficiency parameters needed to be specified and described so that users of the technology inventory can understand what the recorded data represents.

For enhanced readability of this report, the actual specifications of parameters are presented in 0. It holds the longer, more descriptive, definitions and specifications of the parameters. The annex is thought to serve as a look-up section when seeking information on a particular parameter from the technology inventory.

The report and 0 in particular can be viewed as a reference document to accompany the populated inventory in an attempt to avoid confusion on what the listed parameters represent.

The parameters currently included in the inventory are up to date for the Deliverable D1.3. Some changes were made to parameter names during the course of T1.2 work and Case Study development. They are described group-wise, following the overall structure that was presented in Section 2.2 above.

3 Description of the EcoWater indicators

The parameters for each technology are thought to serve as a basis for the impact assessment from each case study, i.e. the eco-efficiency evaluation. Eco-efficiency indicators are basically a set of indicators, based on economic terms and several environmental midpoint indicators. The environmental midpoint indicators are calculated based on parameter value and a characterisation factor, according to Life Cycle Impact Assessment (LCIA) methodology (JRC, 2011).

Table 2 illustrates the midpoint indicators used in the assessment of the environmental performance of the EcoWater meso-level water use system. The adoption of such indicators is proposed by the LCIA methodology and the ISO standard on eco-efficiency (Guinée, 2001).

A comprehensive list of the midpoint environmental impact categories, relevant to EcoWater Case Studies is presented in Annex II. Apart from a description and the unit of measure, Annex II presents all the relevant resources and/or emissions to be included in the calculation of the environmental performance and the values of the corresponding characterisation factors.

Table 2 Environmental midpoint impact indicators

No	Midpoint impact category	Unit of measure
1	Climate change	$tCO_{2,eq}$
2	Ozone depletion	kgCFC-11$_{eq}$
3	Aquatic Eutrophication	$kgPO_{4,eq}$ or $kgNO_{x,eq}$
4	Acidification	$kgSO_{2,eq}$
5	Human toxicity	kg1,4DCB$_{eq}$ or CTU$_h$
6	Ecotoxicity 6.a Aquatic 6.b Terrestrial	kg1,4DCB$_{eq}$ or CTU$_e$
7	Respiratory inorganics	$kgPM_{10,eq}$
8	Ionizing radiation	kBq U-235$_{air,eq}$
9	Photochemical ozone formation	$kgC_2H_{4,eq}$
10	Resource depletion 10.a Minerals 10.b Fossil fuels 10.c Water	kgSb$_{eq}$ or kgFe$_{eq}$ MJ or TOE m^3
11	Land use	ha

4 Innovative technologies in the water use sector

The main objective of the EcoWater project is to propose eco-efficiency indicators for assessing technologies, using water service systems as case application examples. This will enhance the understanding of how innovative technological changes in water systems interrelate and influence the economic and environmental profile and the overall eco-efficiency of water use in different sectors.

One of the outcomes of the project is the inventory from this deliverable that includes novel technologies relevant to the context of the EcoWater Case Studies and describes their main environmental and cost parameters (Task 1.2). The inventory will also be incorporated in the EcoWater Toolbox, as part of Task 5.3.

This section aims to provide a brief representation of meso-level water use systems, as these are analysed in the EcoWater Case Studies, and to describe how the application of new and/or innovative technologies can contribute in the overall improvement of such systems in terms of eco-efficiency. It is structured as follows:

- Section 4.1 is dedicated to the description of meso-level water use systems;
- Section 4.2 describes the classification of technologies and the criteria for technology selection in the examined water use systems.

Annex III complements this section and presents the thus far proposed technologies, and brief descriptions of these based on the available literature

4.1 The meso-level water use system

A meso-level water use system combines the typical **water supply chain** with the corresponding **water use chain**, as illustrated in Figure 1. It incorporates a specific water use with all the processes needed to render the water suitable (both qualitatively and quantitatively) for this use, and the treatment and discharge of the generated effluents to the environment.

The boundaries of the system encompass all the processes related to the water supply and the water use chains. These processes can be grouped into four generic stages:

- Stage 1: **Water Abstraction and Distribution**
- Stage 2: **Water Treatment**
- Stage 3: **Water Use**
- Stage 4: **Wastewater Treatment**

Each process represents an activity, implementing a specific technology, where generic materials (water, raw materials, energy, etc.) are processed and transformed into other materials, while releasing emissions external to the system (air, land, water).

The economic analysis of the meso-level water use system also entails the consideration of the interdependencies and the socio-economic interactions of all the heterogeneous actors involved in the water supply and production chain. As a result, the meso-level water use system has a third significant component: the **water value chain**.

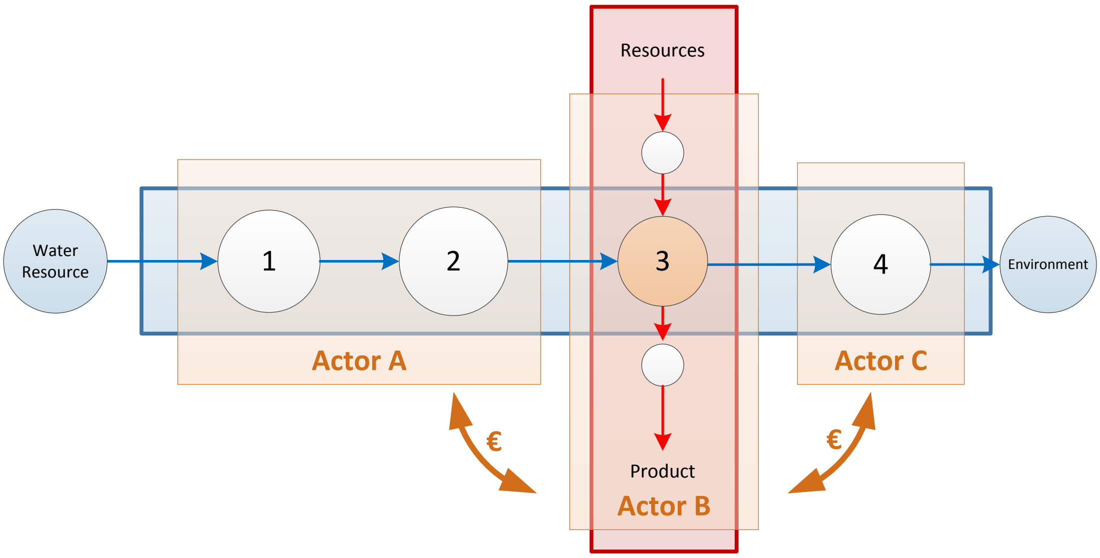


Figure 1. A representation of the meso-level water use system.

4.2 Innovative technologies in a meso level water use system

The upgrading of the value chain of a water use system can be achieved through one or more of the following (Humphrey & Schmitz, 2000):

- Process upgrading, which will result in a more efficient transformation of the inputs into outputs, by rearranging the production line, by introducing new technologies or by recycling/reusing the generated wastewater/effluents;
- Product upgrading, by changing to a more profitable product line (i.e. a product with higher economic value); and
- Functional upgrading, by acquiring new functions in the value chain (i.e. marketing).

In EcoWater, the focus is on process or product upgrading, by introducing technologies which reduce the overall environmental impact or improve the quality/quantity of the final product. The following paragraphs include i) the list of technologies so far, as these have been proposed by the EcoWater Case Studies, to be further developed through literature review and ii) the criteria for the selection of technologies to be assessed in the final phase of the Project.

4.2.1 Technology Classification

A preliminary list of innovative technologies has been identified, based on the mapping of the system in the baseline scenario and the identification of the system vulnerabilities and the environmentally weak stages. Technologies are classified according to the stage at which they are implemented (Figure 2):

1. Technologies in the water supply chain (common in all water use systems); implemented either upstream (e.g. water treatment) or downstream (e.g. wastewater treatment) of the water use stage: Stage 1, 2, and 4.

2. Technologies in the production chain: Stage 3.

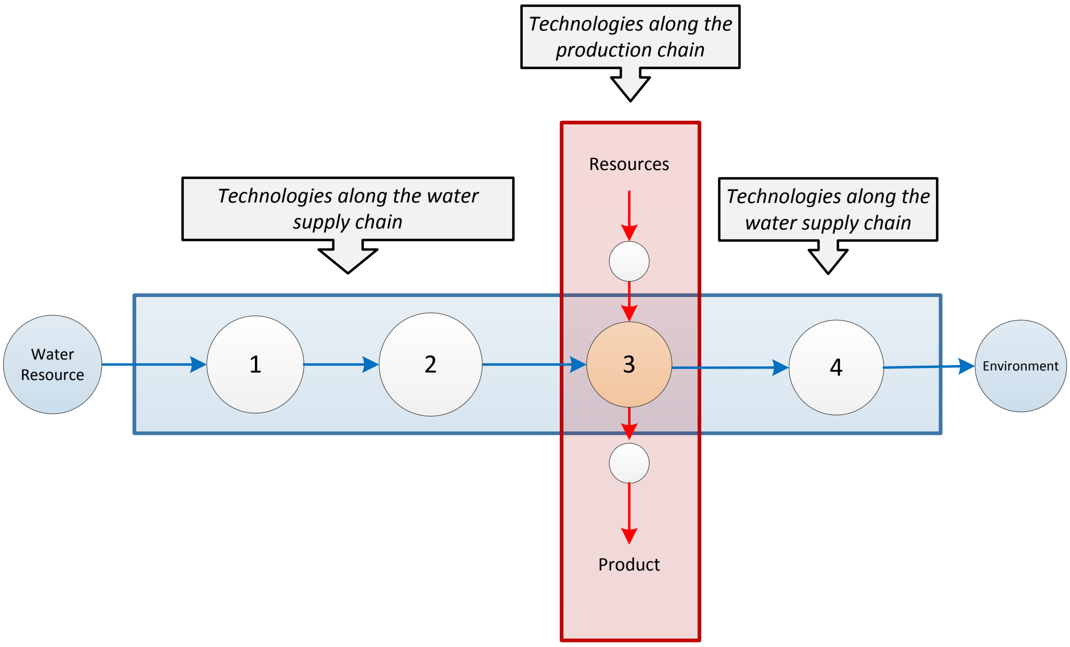


Figure 2. Innovative technologies implementation in different stages of water system.

4.2.1.1 *Water supply chain technologies*

Stage 1. Water Abstraction and Distribution

The proposed technologies for the water abstraction and distribution stage focus on energy saving and water pressure management and are presented in Table 3.

Table 3. Technologies for the water abstraction and distribution stage

1.	Multi-user electronic delivery hydrants
2.	Pressure reducing valves
3.	Hydropower generator, functioning as a pressure reduction valve
4.	Variable-speed pumps
5.	Smart pumping
6.	Variable tariffs of water supply – demand
7.	Variable tariffs of water supply – energy
8.	Alter current pressure head delivery

Stage 2. Water Treatment

The proposed technologies for the water treatment stage focus on water quality upgrade and water pressure management and they are presented in Table 4.

Table 4. Technologies for the water treatment stage.

1.	UV-treatment
2.	Carbon filtration
3.	Membrane distillation for incoming water
4.	Electrodialysis and Ion exchange (EDI)

Stage 4. Wastewater Treatment

The proposed technologies for the wastewater treatment stage focus on water quality upgrade, energy saving and reduction of pollutant emissions and are presented in Table 5.

Table 5. Technologies for the wastewater treatment stage.

1.	Advanced phosphorus recovery technologies
2.	Ultra filtration
3.	Carbon filtration
4.	Reverse osmosis
5.	Membrane bioreactors
6.	Micropollutants removal technologies
7.	Energy recovery (e.g. heat recovery from wastewater)
8.	Solar sludge drying
9.	Water reuse for domestic water users
10.	Water reuse for non-domestic water users
11.	Dissolved air flotation (with chemicals)
12.	Activated sludge
13.	Anaerobic pre-treatment

4.2.1.2 Production chain technologies

Agricultural sector

The proposed technologies for the agriculture water use systems (CS#1 & 2) focus on water and energy saving and are presented in Table 6.

Table 6. Technologies for the agricultural sector

1.	Shifting of irrigation methods (from sprinkle to mini-sprinkle & drip irrigation)
2.	Sub-surface drip irrigation (SDI)
3.	Regulated deficit irrigation (RDI)
4.	On-farm devices for precision irrigation
5.	Variable rate irrigation system
6.	Super-high density crop production
7.	Biological production

Urban sector

The proposed technologies for the urban water use systems (CS#3 & 4) focus on water and energy saving, as well as the reduction of pollutant emissions to the environment and are presented in Table 7.

Table 7. Technologies for the urban sector

1.	Water saving appliances (low flushing toilets, shower heads, dishwashers)
2.	Solar water heating
3.	Toilet flush 4 litres
4.	Water saving showerhead

Industrial sector

The proposed technologies for the industrial water systems (CS#5, 6, 7 & 8) focus on water saving in production chain processes and are presented in Table 8.

Table 8. Technologies for the industrial sector

1.	Dyeing with natural colours
2.	Smart cooling of cooling water
3.	Adaptive ratio of electrical and thermal energy production
4.	Thermal energy storage
5.	Metal surface treatment of cabins (improved phosphating technology)
6.	Condenser for recovery of water from spray tower exhaust air
7.	Dry filter instead of overspray in paint shop
8.	Combined Heat and Power Production (CHP)

4.2.2 Technology Selection Criteria

The selection of technologies, to be subsequently assessed in the third phase of the project, will be based on the following criteria:

- Innovation (qualitative criterion);
- Maturity (qualitative criterion);
- Availability in market (qualitative criterion); and
- Economic & Environmental Performance (quantitative).

Innovation

The term innovation is used as the application of a new and better process or as the introduction of a new product (Archibugi, 1988).

Maturity

A mature technology is a technology with relatively high readiness level. It has been in use for long enough that most of its initial problems have been reduced by further development. A mature technology may have not seen widespread use, but its scientific background is well understood.

Availability

Technologies that have been assessed should be available in the market. This means that there are available data (e.g. cost data) which are necessary for assessing their performance in a water system.

Performance

The performance criterion has two components, both of which can be measurable; the economic component can be measured in absolute values, while the environmental component can be measured either in absolute or relative terms (e.g. % removal of pollutants). The contribution of the technology towards the eco-efficiency improvement of the system can subsequently be estimated as the ratio of the two values.

5 Discussion

This report, as described in the DoW, describes structured information on technologies for improving the eco-efficiency of water use in agricultural, urban, and industrial sectors.

The technology inventory holds information and data on several current but also innovative new technologies for the water using sectors. Technologies were chosen in light of the eight project Case Studies and the inventory data stems from the work performed for each individual Case Study, by different project partners. A tight communication between the project partners has been vital to get a mutual understanding about what kind of data to search for and how to complete the inventory. Nevertheless, most data that populates the technology inventory are related to the specific Case Studies and may not be easily extrapolated to other uses of the same technology. A future user of the data should always be aware of the context of the data and only adopt such data which can be reasonably similar for the new application of the chosen technology. On the other hand, the technology data for which the context is generic would only need a quick verification by the future user before being applied in a model. It is always up to the future user of data from the inventory to judge if the technology data is applicable in the context of the new Case Study.

During the data collection phase, it was clear that it is not always easy to find representative data. Not surprisingly, this was especially true for the innovative technologies.

The technology inventory will be integrated in the EcoWater toolbox. In its present form, the technology inventory should be seen more as an inspirational data source rather than a “plug-and-play”.

For a future user who wants to add a technology to the web-tool, it can be useful to start looking at which parameters are included in the environmental indicators. After that, one can start researching the data for these parameters for each technology to be modelled.

6 References

Annex I – ”Description of Work”, EcoWater, Grant agreement no:282882.

Archibugi, D. (1988). In Search of a Useful Measure of Technological Innovation (to Make Economists Happy without Discontenting Technologists). *Technological Forecasting and Social Change* , 34, 253-277.

DOE (2011). *Technology Readiness Assessment Guide*. United States Department of Energy, Office of Management. (DOE G 413.3-4).

Guinée, B. J. et al., (2001). *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards.* Dordrecht: Kluwer Academic Publishers.

Humphrey, J., & Schmitz, H. (2000). *Governance and Upgrading: Linking Industrial Cluster and Global Value Chain Research.* Working Paper 120, IDS.

JRC. (2011). European Commission – Joint Research Centre – Institute for Environment and Sustainability: *International Reference Life Cycle Data system (ILCD) Handbook: Recommendations for Life Cycle Impact Assessment in the European context.* First Edition. Luxembourg: Publication Office of the European Union.

OPTIMA project website, www.ess.co.at/OPTIMA, visited Jan-2012.

Annex I Parameter specification

The parameters are specified below. The headings are written in the form of “category”/”group”/”name” for parameters that are described individually or “category”/”group”/ for parameters that are described collectively. The order of parameters follows the overall structure of the technology inventory template, as described in Section 2.5.

Performance / - / Technology lifetime

Unit:	years
Definition:	Number of years from when the technology is put into use and until it no longer works or becomes obsolete.
Description:	Performance parameters are as of yet ungrouped. They are a category of parameters that describe general performance (not efficiency) of the technology.

Performance / - / Reliability

Unit:	%
Definition:	The parameter represents the % of time for a technology to function as intended. An estimated Reliability of 95% means one can expect malfunction during 5% of the operative time for the technology.
Description:	Performance parameters are as of yet ungrouped. They are a category of parameters that describe general performance (not efficiency) of the technology.

Economic / Cost /

Parameter name [suggested unit]	Clarification	Used by Case Study
Technology interest rate [%/year]	-	#4; #7
Investment cost (CAPEX) [€]	Capital Expenditures	#1; #3; #4; #6; #7; #8
Operations cost: Total (OPEX) [€/m^3]	Operational Expenditures	#1; #3; #4; #6; #8
Operations cost: Natural gas [€/year]	-	#7
Operations cost: Raw materials [€/year]	-	#7
Operations cost: Electricity [€/m^3]	-	#2; #3; #4; #7; #8
Operations cost: Waste water [€/year]	-	#7
Operations cost: Chemicals [€/m^3]	-	#3; #4; #7; #8
Operations cost: Water [€/m^3]	-	#2; #7
Operations cost: Farm management (production cost) [€/ha]	Cost of production without water and energy costs	#2
Operations cost: Irrigation delivery service paid by farmers [€/m^3]	Tariff for water consumption above 2,050 m^3/ha	#1

Maintenance cost [€/year]	-	#3; #4; #6; #8
Yearly financial costs of technology [€/year]	-	#3; #4; #6
Financial costs to treat $1m^3$ [€/m^3]	-	#3; #4

Description: Parameters representing a cost incurred from using the technology. The cost could be e.g. reported as a total cost or individually for the resources used when applying the technology.

Economic / Value /

Parameter name [suggested unit]	Clarification	Used by Case Study
Benefits for actors changing technology/substance/crop [€/year]		#6
Value from by-products (e.g. biogas) [€/year]		#3; #7
Value from export of electricity to the grid [€/year]		#7
Value from products [€/year]		#7

Description: Parameters representing a value created from using the technology. The value could be e.g. added value of water, value from by-products or other value to the user of the technology.

Environmental / Emissions to air /

Parameter name [suggested unit]	Midpoint impact category	Used by Case Study
CH_4 [t/year]	Climate change	-
CO_2 [t/year]	Climate change	#2; #7
N_2O formation in WWTP [kg/year]	Climate change	#7
SO_x [kg/year]	Acidification potential	#7

Clarification: Substances emitted to air by the technology, affecting its quality.

Description: Can include a range of substances important for air quality or other environmental impact categories

Environmental / Water quality influence /

Parameter name [suggested unit]	Midpoint impact category	Used by Case Study
Ammonia nitrogen (NH_4-N) [kg/year]	Aquatic Eutrophication	#7
Nitrogen total (N) [Δmg/l]	Aquatic Eutrophication	#3; #7
PO_4 [Δmg/l]	Aquatic Eutrophication	#3
Phosphorus total (P) [Δmg/l]	Aquatic Eutrophication	#3; #4; #7; #8
BOD (Biological oxygen demand) [Δmg/l]	Parameter of interest. Not within the chosen indicators	#3; #4; #8
COD (Chemical oxygen demand) [Δmg/l]	Aquatic Eutrophication	#3; #4; #7; #8
TSS (Total suspended solids) [Δmg/l]	Parameter of interest. Not within the chosen indicators	#3
Micro pollutants [kg/year]	Parameter of interest. Not	#7

	within the chosen indicators	
Mineral oil [Δmg/l]	Parameter of interest. Not within the chosen indicators	#8
Nickel (Ni) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5; #8
Zinc (Zn) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5; #8
TEH (Total extractable hydrocarbons) [Δmg/l]	Parameter of interest. Not within the chosen indicators	#5
Cadmium (Cd) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Lead (Pb) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#4; #5
Mercury (Hg) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Chromium (Cr) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Copper (Cu) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Arsenic (As) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Selenium (Se) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Antimony (Sb) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Tin (Sn) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Cobalt (Co) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Molybdenum (Mo) [Δmg/l]	Human Toxicity; Aquatic Ecotoxicity	#5
Temperature or emitted thermal load [Δdegrees °C]	Parameter of interest. Not within the chosen indicators	#6

Clarification: Substances (pollutants) in the water, affecting its quality.

Description: The parameter group describes the difference in concentration for the substances (parameters) before and after the technology step in the node. For example a filter absorbing PAH, will give a negative value since the concentration of PAH in the water is lower after the filter.

Environmental / Water use /

Parameter name [suggested unit]	Midpoint impact category	Used by Case Study
Total volume per year [m^3/year]	Parameter of interest. Not within the chosen indicators	#1; #2; #3; #4; #5; #6; #8
Re-used water [m^3/year]	Parameter of interest. Not within the chosen indicators	#4
Water discharged after use of technology [m^3/year]	Parameter of interest. Not within the chosen indicators	#3; #6
Water lost (leakages) [m^3/year]	Parameter of interest. Not within the chosen indicators	#3; #5
Surface water [m^3/year]	Resource Depletion – Fresh Water	#3; #4; #5; #6; #8
Groundwater [m^3/year]	Resource Depletion – Fresh Water	#4; #5; #8
Unspecified water [m^3/year]	Parameter of interest. Not	#4; #8

	within the chosen indicators	
Fresh water use [m^3/year]	Resource Depletion – Freshwater	#7

Clarification: Water used and/or processed by the technology in that node.

Description: The parameter group describes different uses of water in the technology.

Environmental / Resource use /

Parameter name [suggested unit]	Midpoint impact category	Used by Case Study
Total energy [kWh/year]	Resource Depletion – Fossil Fuels	#1; #2; #3; #4; #6; #8
Energy – Electricity [kWh/year]	Climate Change (via country specific factor for electricity production)	#3; #4; #6; #7; #8
Energy – Heat from CHP [kWh/year]	Parameter of interest. Not within the chosen indicators	#3
Energy – Electricity Renewable [kWh/year]	Parameter of interest. Not within the chosen indicators	#3
Energy – Oil [kWh/year]	Resource Depletion – Fossil Fuels	#6, #8
Energy – Gas [kWh/year]	Resource Depletion – Fossil Fuels	#6, #7; #8
Energy – Transport Fuels	Resource Depletion – Fossil Fuels	#3
Energy – District heating [kWh/year]	Climate Change (via factor for DH production)	#8
Chemicals (applications specific) [t/year]	Parameter of interest. Not within the chosen indicators	#8
$FeCl_3$ at WWTP and polymers at biogas facility	Parameter of interest. Not within the chosen indicators	#7
Chemicals ($AlSO_4$) [t/year]	Parameter of interest. Not within the chosen indicators	#3
Chemicals (Cl_2) [t/year]	Parameter of interest. Not within the chosen indicators	#3
Chemicals ($FeCl_3$) [t/year]	Parameter of interest. Not within the chosen indicators	#3
Chemicals (Flocculants) [t/year]	Parameter of interest. Not within the chosen indicators	#3
Zinc (in chemicals) [kg/year]	Resource Depletion – Minerals	#8
Nickel (in chemicals) [kg/year]	Resource Depletion – Minerals	#8
Phosphorus (in chemicals) [kg/year]	Resource Depletion – Minerals	#8
NaCl [kg/year]	Parameter of interest. Not within the chosen indicators	#7
Other chemicals - mainly HCl and NaOH [kg/year]	Parameter of interest. Not within the chosen indicators	#7
Cleaning chemicals [kg/year]	Parameter of interest. Not within the chosen indicators	#7

Clarification: Resources used by the technology.

Description: The parameters in the group describe different resource uses, e.g. electricity used by the technology, or chemicals etc.

Environmental / Solid waste

Parameter name [suggested unit]	Midpoint impact category	Used by Case Study
Solid waste for waste treatment (e.g. landfill, incineration, etc.) [t/year]	Parameter of interest. Not within the chosen indicators	#3; #8

Clarification: Solid waste stemming from use of the technology

Description: The parameters in the group are divided into waste that needs treatment with e.g. incineration or landfill, and waste that could be used as a resource, e.g. sludge as fertilizer.

Environmental / Background impacts /

Parameter name [suggested unit]	Midpoint impact category	Used by Case Study
Background impact from technology production [narrative]	Parameter of interest. Not within the chosen indicators	#6

Description: Environmental impacts caused during technology production, i.e. not during technology use in the node.

Efficiency / Energy /

Parameter name [suggested unit]	Clarification	Used by Case Study
Energy use/volume of water used [kWh/m^3]		#2; #6; #8
Ratio energy supply to demand [Pth/Dth = J/J]		#6
Energy produced per m^3 cooling water [J/m^3]		#6
Reduction usage of gas for heating [m^3/year]		#6
Discharged amount of heat in recipient [J/year]		#6

Description: Efficiency parameters relating to energy.

Efficiency / Physical /

Parameter name [suggested unit]	Clarification	Used by Case Study
Water use/area [m^3/ha]		#2
Crop production/volume of water used [t/m^3]		#2

Clarification: “Water use per area” can be applied to both “area of a specific crop”, “area of a specific irrigation technology” and “area of a specific production system”.

Description: Efficiency parameters relating to the use of a resource or the production volume.

Annex II Midpoint environmental impact categories

This annex presents the midpoint categories used in the EcoWater project.

Climate Change	
Description	Climate change is defined as the impact of human emissions on the radiative forcing (heat radiation absorption) of the atmosphere, which results in the rise of the earth's surface temperature (greenhouse effect).
Indicator	Radiative forcing as Global Warming Potential (GWP): reflects the relative effect of the emissions of greenhouse gases into the air, considering a fixed time period (i.e. 100 years).
Unit of Measure	$tCO_{2,eq}$
Characterization factors of relevant supplementary resources / emissions	Carbon Dioxide (CO_2): 1 t $CO_{2,eq}/tCO_2$ Methane (CH_4): 25 $tCO_{2,eq}/tCH_4$ Nitrous Oxide (N_2O): 298 $tCO_{2,eq}/tN_2O$ Methylene Chloride (CH_2Cl_2): 8.7 $tCO_{2,eq}/tCH_2Cl_2$ Hydrofluorocarbons; e.g. HFC-134a: 1430 $tCO_{2,eq}$/tHFC-134a Perfluorocarbons; e.g. CF_4: 7390 $tCO_{2,eq}/tCF_4$ Sulphur hexafluoride (SF_6): 22800 $tCO_{2,eq}/tSF_6$
Relevant EcoWater Case Studies	All
References	(Guinée, et al., 2001; IPCC, 2007)

Stratospheric Ozone Depletion	
Description	Stratospheric ozone depletion is the thinning of the stratospheric ozone layer due to anthropogenic emissions (i.e. CFCs and Halons) and results in a greater fraction of solar UV-B radiation reaching the earth's surface.
Indicator	Ozone Depletion Potential (ODP): expresses the amount of ozone destroyed by ozone depleting substances, considering steady-state ozone depletion.
Unit of Measure	$kgCFC\text{-}11_{,eq}$
Characterization factors of relevant supplementary resources / emissions	Chlorofluorocarbons: 1 $kgCFC\text{-}11_{,eq}$/ kgCFC-11, CFC-113: 0.90 $kgCFC\text{-}11_{,eq}$/kgCFC-113 Hydrochlorofluorocarbons: 0.026 $kgCFC\text{-}11_{,eq}$/kg HCFC-124 Halons; e.g. Halon-1301: 12 $kgCFC\text{-}11_{,eq}$/kg Halon-1301 Methyl Bromide (CH_3Br): 0.37 $kgCFC\text{-}11_{,eq}/kgCH_3Br$ Tetrachloromethane (CCl_4): 1.2 $kgCFC\text{-}11_{,eq}/kgCCl_4$
Relevant EcoWater Case Studies	All

References	(Guinée, et al., 2001; Goedkoop, et al., 2008; EPA, 2006)
Eutrophication	
Description	Eutrophication covers all potential impacts of excessively high environmental levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In addition, high nutrient concentrations may also render surface waters unacceptable as a source of drinking water.
Indicator	Eutrophication Potential (EP): measures the fraction of nutrients, which cause over-fertilization of water.
Unit of Measure	$kgPO_{4,eq}$ or $kgNO_{x,eq}$
Characterization factors of relevant supplementary resources / emissions	Ammonia (NH_3): 0.35 $kgPO_4^{3-}{}_{,eq}/kgNH_3$ Ammonium (NH_4^+): 0.33 $kgPO_4^{3-}{}_{,eq}/kgNH_4^+$ Nitrates (NO_3^-): 0.1 $kgPO_4^{3-}{}_{,eq}/kgNO_3^-$ Nitric Acid (HNO_3): 0.1 $kgPO_4^{3-}{}_{,eq}/kgHNO_3$ Nitrogen Total (N): 0.42 $kgPO_4^{3-}{}_{,eq}/kgN$ Nitrogen Monoxide (NO): 0.2 $kgPO_4^{3-}{}_{,eq}/kgNO$ Nitrogen Dioxide (NO_2): 0.13 $kgPO_4^{3-}{}_{,eq}/kgNO_2$ Nitrogen Oxides (NO_x): 0.13 $kgPO_4^{3-}{}_{,eq}/kgNO_x$ Nitrous Oxide (N_2O): 0.27 $kgPO_4^{3-}{}_{,eq}/kgN_2O$ Phosphates (PO_4^{3-}): 1 $kgPO_4^{3-}{}_{,eq}/kgPO_4^{3-}{}_{,eq}$ Phosphoric Acid (H_3PO_4): 0.97 $kgPO_4^{3-}{}_{,eq}/kgH_3PO_4$ Total Phosphorus (P): 3.06 $kgPO_4^{3-}{}_{,eq}/kgP$ Phosphorus Oxide (P_2O_5): 1.34 $kgPO_4^{3-}{}_{,eq}/kgP_2O_5$ Chemical Oxygen Demand: 0.022$kgPO_4^{3-}{}_{,eq}/kgCOD$
Relevant EcoWater Case Studies	All
References	(Guinée, et al., 2001)
Acidification	
Description	Acidification refers to the processes that increase the acidity of water and soil systems through hydrogen ion concentration and it is caused by the acidifying effects of anthropogenic emissions (i.e. NO_x, SO_2).
Indicator	Acidification Potential (AP): describes the impacts of emissions of acidifying substances on natural ecosystems. The time span is eternity and the geographical scale varies between local and continental.
Unit of Measure	$kgSO_{2,eq}$
Characterization factors of relevant supplementary resources / emissions	Ammonia (NH_3): 1.88 $kgSO_{2,eq}/kgNH_3$ Hydrogen Chloride (HCl): 0.88 $kgSO_{2,eq}/kgHCl$ Hydrogen Fluoride (HF): 1.60 $kgSO_{2,eq}/kgHF$

	Hydrogen Sulfide (H_2S): 1.88 $kgSO_{2,eq}/kgH_2S$ Nitrogen Oxides (as NO_2): 0.70 $kgSO_{2,eq}/kgNO_2$ Phosphoric Acid (H_3PO_4): 0.98 $kgSO_{2,eq}/kgH_3PO_4$ Sulphur Dioxide (SO_2): 1 $kgSO_{2,eq}/kgSO_2$ Sulphuric Acid (H_2SO_4): 0.65 $kgSO_{2,eq}/kgH_2SO_4$
Relevant EcoWater Case Studies	All
References	(Guinée, et al., 2001; Goedkoop, et al., 2008)
Human Toxicity	
Description	Human toxicity refers to the impacts of toxic substances present in the environment on human health.
Indicator	Human Toxicity Potential (HTP): expresses the degree to which a chemical substance elicits an adverse effect on the biological system of human exposed to it over a designated time period (e.g. 100 years).
Unit of Measure	$kg1,4DCB_{eq}$ or CTU_h
Characterization factors of relevant supplementary resources / emissions	More than 450 substances, including polycyclic aromatic HCs (PAHs), halogenated aromatic and non-aromatic HCs, alkanes, alkenes. Indicative characterization factors are the following: **Textile Industry:** • Chromium (VI) (to fresh water): 2.1 $kg1.4DCB_{,eq}/kg$ Cr **Automotive Industry:** • Nickel (to fresh water): 331.08 $kg1.4DCB_{,eq}/kg$ Ni • Zinc (to fresh water): 0.584 $kg1.4DCB_{,eq}/kg$ Zn **Urban Water Systems** • Cadmium (to fresh water): 22.89 $kg1.4DCB_{,eq}/kg$ Cd
Relevant EcoWater Case Studies	CS#5, CS#8
References	(Guinée, et al., 2001)
Ecotoxicity - Aquatic	
Description	Freshwater aquatic ecotoxicity refers to the impacts of toxic substances on freshwater aquatic ecosystems.
Indicator	Freshwater aquatic ecotoxicity potential (FAETP): describes fate, exposure and effects of toxic substances to air, water, and soil. The time horizon is infinite and the indicator applies at global, continental, regional, local scale.
Unit of Measure	$kg1,4DCB_{eq}$ or CTU_e
Characterization factors of relevant supplementary	More than 450 substances, including polycyclic aromatic HCs (PAHs), halogenated aromatic and non-aromatic HCs, alkanes, alkenes. Indicative characterization factors are the

resources / emissions	following: **Textile Industry:** • Chromium (VI) (to freshwater): 27.65 kg1.4DCB$_{,eq}$/kgCr **Automotive Industry:** • Nickel (to freshwater): 3237 kg1.4DCB$_{,eq}$/kg Ni • Zinc (to freshwater): 91.71 kg1.4DCB$_{,eq}$/kg Zn **Urban Water Systems** • Cadmium (to freshwater): 1523 kg1.4DCB$_{,eq}$/kg Cd
Relevant EcoWater Case Studies	CS#3, CS#4, CS#5, CS#7, CS#8
References	(Guinée, et al., 2001)
Ecotoxicity - Terrestrial	
Description	Terrestrial ecotoxicity refers to toxic substances on terrestrial ecosystems.
Indicator	Terrestrial Ecotoxicity Potential (TETP): describes fate, exposure and effects of toxic substances to air, water, and soil. The time horizon is infinite and the indicator applies at global, continental, regional, local scale.
Unit of Measure	kg1,4DCB$_{eq}$ or CTU$_e$
Characterization factors of relevant supplementary resources / emissions	More than 450 substances, including polycyclic aromatic HCs (PAHs), halogenated aromatic and non-aromatic HCs, alkanes, alkenes. Indicative characterization factors are the following: **Textile Industry:** • Chromium (VI) (to agri. soil): 6300 kg1.4DCB$_{,eq}$/kg Cr **Automotive Industry:** • Nickel (to agri. soil): 238.5 kg1.4DCB$_{,eq}$/kg Ni • Zinc (to agri. soil): 24.5 kg1.4DCB$_{,eq}$/kg Zn **Urban Water Systems** • Cadmium (to agri. soil): 166.8 kg1.4DCB$_{,eq}$/kg Cd
Relevant EcoWater Case Studies	CS#3, CS#4, CS#5, CS#7, CS#8
References	(Guinée, et al., 2001)
Respiratory Inorganics	
Description	Respiratory effects resulting from particulate matter (PM) due to emissions of primary or secondary particulates. Emissions of SO$_2$ and NO$_x$ that create sulphate and nitrate aerosols are included in secondary emissions, resulting from combustion.
Indicator	Particulate Matter Potential (PMP): accounts for

	environmental fate, exposure and dose-response of a pollutant (Midpoint).
Unit of Measure	$kgPM_{2.5,eq}$
Characterization factors of relevant supplementary resources / emissions	PM_{10} $PM_{2.5}$ $PM_{0.1}$
Relevant EcoWater Case Studies	
References	(Guinée, et al., 2001)
Ionizing Radiation	
Description	Ionizing radiation covers the impacts arising from emissions of radioactive substances to air, water and soil, as well as direct exposure to radiation (α-, β-, γ-rays, neutrons), which is harmful to both human beings and animals.
Indicator	Ionizing Radiation Potential (IRP): measures the effects caused by the adsorbed radiation, taking into account the emissions and the calculation of their radiation behaviour and burden.
Unit of Measure	kBq $U\text{-}235_{air,eq}$
Characterization factors of relevant supplementary resources / emissions	Indicative characterization factors are the following: C-14 (to air): 0.94 kBq $U\text{-}235_{air,eq}$/kBq C-14 Pu-alpha (to air): 4.1 kBq $U\text{-}235_{air,eq}$/kBq Pu-alpha Ra-226 (to air): 0.045 kBq $U\text{-}235_{air,eq}$/kBq Ra-226 U-235 (to air): 1 kBq $U\text{-}235_{air,eq}$/kBq $U\text{-}235_{air,eq}$ Co-60 (to rivers): 2.2 kBq $U\text{-}235_{air,eq}$/kBq Co-60 Cs-137 (to rivers): 8.2 kBq $U\text{-}235_{air,eq}$/kBq Cs-137 Sb-125 (to ocean): 0.0071 kBq $U\text{-}235_{air,eq}$/kBq Sb-125
Relevant EcoWater Case Studies	
References	(Guinée, et al., 2001; Frischknecht, et al., 2000)
Photochemical Ozone Formation	
Description	Photochemical ozone formation refers to the formation of reactive chemical compounds such as ozone by the action of sunlight on certain primary air pollutants (VOCs, CO, NO_x).
Indicator	Photochemical Ozone Creation Potential (POCP): measures the impacts from emissions of substances to air.
Unit of Measure	$kgC_2H_{4,eq}$
Characterization factors of relevant supplementary resources / emissions	Indicative characterization factors are the following: 1-Butene: 1.08 $kgC_2H_{4,eq}/kgC_4H_8$ Carbon monoxide: 0.027 $kgC_2H_{4,eq}/kgCO$ Isobutene: 0.307 $kgC_2H_{4,eq}/kgC_4H_8$

	Methane: 0.006 $kgC_2H_{4,eq}/kgCH_4$ Nitrous oxides: 0.028 $kgC_2H_{4,eq}/kgNO_x$ Propylene: 1.12 $kgC_2H_{4,eq}/kgC_3H_6$ Sulphur dioxide: 0.048 $kgC_2H_{4,eq}/kgSO_2$ Tetrachloroethylene: 0.029 $kgC_2H_{4,eq}/kgC_2Cl_4$
Relevant EcoWater Case Studies	
References	(Guinée, et al., 2001)
Resource Depletion - Minerals	
Description	Resource depletion refers to the decreasing availability of resources (minerals), as a result of their consumption beyond the rate of renewal/replacement.
Indicator	Resource Depletion Potential (RDP): measures the consumption of non-renewable resources, i.e. minerals.
Unit of Measure	$kgSb_{eq}$ or $kgFe_{eq}$
Characterization factors of relevant supplementary resources / emissions	All elements. Indicative characterization factors are the following: Aluminium (Al): 1×10^{-8} kg $Sb_{,eq}$/ kg Al Antimony (Sb): 1.00 kg $Sb_{,eq}$/ kg Sb Bromine (Br): 0.00667 kg $Sb_{,eq}$/ kg Br Cadmium (Cd): 0.33 kg $Sb_{,eq}$/ kg Cd Chlorine (Cl): 4.86×10^{-8} kg $Sb_{,eq}$/ kg Cl Iron (Fe): 8.43×10^{-8} kg $Sb_{,eq}$/ kg Fe Lead (Pb): 0.0135 kg $Sb_{,eq}$/ kg Pb Magnesium (Mg): 3.73×10^{-9} kg $Sb_{,eq}$/ kg Mg Manganese (Mn): 1.38×10^{-5} kg $Sb_{,eq}$/ kg Mn Nickel (Ni): 0.000108 kg $Sb_{,eq}$/ kg Ni Phosphorus (P): 8.44×10^{-5} kg $Sb_{,eq}$/ kg P Sodium (Na): 8.42×10^{-11} kg $Sb_{,eq}$/ kg Na Sulfur (S): 0.000358 kg $Sb_{,eq}$/ kg S Zinc (Zn): 0.000992 kg $Sb_{,eq}$/ kg Zn
Relevant EcoWater Case Studies	CS#8
References	(Guinée, et al., 2001)
Resource Depletion – Fossil Fuels	
Description	Resource depletion refers to the decreasing availability of resources (fossil fuels), as a result of their consumption beyond the rate of renewal/replacement.
Indicator	Resource Depletion Potential (RDP): measures the consumption of non-renewable resources, i.e. fossil fuels.
Unit of Measure	MJ or TOE
Characterization factors of	All elements. Indicatively, the calorific values of consumed

relevant supplementary resources / emissions	fuels are the following: Coal hard: 28.9 MJ/kg Coal soft, lignite: 8.4 MJ/kg Natural gas: 38.00 MJ/m^3 Crude oil: 45.6 MJ/kg
Relevant EcoWater Case Studies	All
References	(Guinée, et al., 2001)
Resource Depletion – Freshwater	
Description	Freshwater depletion refers to the decreasing availability of freshwater resources, due to their abstraction. Measures the impacts on freshwater ecosystems due to freshwater abstraction.
Indicator	Resource Depletion Potential (RDP): measures the impacts on freshwater ecosystems due to water resource depletion.
Unit of Measure	m^3 of “ecosystem-equivalent” water
Characterization factors of relevant supplementary resources / emissions	Fresh water abstracted. Withdrawal-to-availability ratio of the river basin (WTA).
Relevant EcoWater Case Studies	All
References	(Guinée, et al., 2001)

References

EPA, 2006. Life Cycle Assessment - Principles and Practice, Cincinnati, Ohio: Scientific Applications International Corporation (SAIC).

Frischknecht, R., Braunschweigb, A., Hofstetterc,, P. & Suterd, P., 2000. Human health damages due to ionising radiation in life cycle impact assessment. Environmental Impact Assessment Review, 20(2), pp. 159-189.

Goedkoop, M., Oele, M., Schryver, A. & Vieira, M., 2008. SimaPro Database Manual Methods library. Netherlands: PRé Consultants.

Guinée, B. J. et al., 2001. Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Dordrecht: Kluwer Academic Publishers.

IPCC, 2007. IPCC Fourth Assessment Report: Climate Change 2007. [Online] Available at: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html [Accessed 30 10 2013].

Annex III List of innovative technologies

This annex describes several innovative technologies, researched in the EcoWater Case Study work.

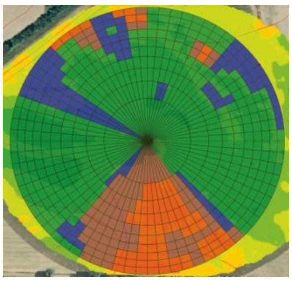
Techology	**Variable Speed Pump**
Short Description	
 *Variable Speed Pump, Irrigation System [2]*	An effective method to regulate the water flow rate in order to meet the demand needs downstream the supply system is through the implementation of a variable speed drive sub-system; the most applicable type is the variable frequency drive (VFD). This technology has the potential to enhance the efficiency of the whole system by consuming the minimum required energy through adjusting the power driving the pump depending on the actual demand rate. Lower flow rates and head also increase pump bearing and seal life, by reducing the hydraulic forces and vibrations/noise acting on the components in motion (e.g. impeller, piston, diaphragm) [1].
General Information	
Sector	Agricultural water systems
Stage	Distribution network - Secondary Network (i.e. from Reservoirs nodes to Blocks distribution networks nodes) [3]
Economic Data	
Technology Lifetime	15 years [3]
Investment Cost	30,000 € [3]
Operation Cost	0.035 Euro/m^3
Environmental Performance	
Water saving	Due to the reduced levels of overall dynamic head, leakages will be minimized and water savings might be achieved.
Energy efficiency	Up to 50% reduction in energy consumption [4]. Head and flow rate can be optimized, resulting in minimal fuel consumption by the motor [2].
Physical efficiency	-
Environmental impacts	Minimization of energy consumption; Potential water savings
Applications/Innovative Character	
Energy Savings Investigation for a pumping station serving an on-demand irrigation system – results 32.9% annual energy savings due to the use of a variable speed drive (VSD) [5].	
References	
[1]	Hydraulic Institute, Europump, U.S. DOE Industrial Technologies Program. (2004). *Variable Speed Pumping, A Guide to Successful Applications.* Retrieved from U.S. Department of Energy, Efficiency & Renewable Energy: http://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/variable_speed_pumping.pdf
[2]	Grundfos Irrigation. (2013, June 17). *More crop per drop with variable speed pumps.* Retrieved from Grundfos: http://www.grundfos.com/content/dam/Global%20Site/Industries%20&%20solutions/waterutility/pdf/Grundfos-Irrigation.pdf
[3]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[4]	Stavale, A. E. (2001). Smart Pumping Systems: The Time is Now. *Canadian International Petroleum Conference, Jun 12 - 14, 2001, Calgary, Alberta.* Seneca Falls, NY USA: Society of Petroleum Engineers [successor to Petroleum Society of Canada].
[5]	Barutçu, F., Fratino, U., Lamaddalena, N. (2007). Energy saving for a pumping station serving an ondemand irrigation system: a study case. In : Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.). *Water saving in Mediterranean agriculture and future research needs [Vol. 1]*. Bari: CIHEAM, 367-379 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.I)

Technology	**Multi – User Electronic Delivery Hydrants**
Short Description	
 *Agricultural Irrigation Hydrant [2]*	An electro-mechanical device is utilized by a multi-user delivery hydrant so as to optimize the effectiveness of the water supply to authorized users. Data regarding the irrigation events can be recorded and stored in an electronic memory for agronomic, statistic, scientific and administrative purposes. This system is programmable in such a way to supply water within specific time slots during the day, aiming at minimizing both the water and the energy consumption. An operating centre, responsible for planning and controlling water distribution would have a critical role in the function of such a centralized and integrated capillary system. The supply (volume and time) of water to each consumer would be continuously regulated by the irrigation authority depending on parameters such as the crop/climatic conditions and the actual water availability. Recent developments of such a technology included the CVA and the HYDROMAT self-feeding systems which are powered by photovoltaic cells, incorporate up to 16 users per hydrant, do not require any human intervention for the consumption readings and have the potential to optimize the system's flow hydrograph [1].
General Information	
Sector	Agricultural water systems
Stage	Distribution Network; Delivery Hydrant
Economic Data	
Technology Lifetime	20 years [3]
Investment Cost	1,200 € [3]
Operation Cost	0.022 €/m^3 (assumed to be 10% of investment, 1 device is responsible for the supply of approximately 5ha of land) [3]
Environmental Performance	
Water saving	Optimization of the water resources for agricultural practices [1]
Energy efficiency	17% (CdTe solar cell); 25% (monocrystalline solar cell); 31% (high concentration multi-junction solar cell) [4]
Physical efficiency	1 hydrant supplies water to 5 ha with an average annual rate: 1,100 m^3/ha [3]
Environmental impacts	Such an ingenious control system allows the improvement of the land productivity, while minimizing the water and energy consumption [1]
Applications/Innovative Character	
Centrally controlled irrigation distribution system (600,000 m pipe network, 14,000 hydrants, 8,775 l/s, 3 years of operation) – Sicily, Italy [1]	
References	
[1]	Antonello, E, Bianchi, C. and Lamaddalena N. (1995). Delivery equipment for a better application of limited water resources in pressurized collective irrigation systems. *New Medit*, 6(4), 54-57.
[2]	Turkish Manufacturers. (2013, July 02). *Agricultural irrigation hydrant Turkey*. Retrieved from turkish-manufacturers: http://turkish-manufacturers.com/products/agricultural-irrigation-hydrant.html
[3]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[4]	ISE, Fraunhofer Institute For Solar Energy Systems. (2013, July). *Photovoltaics Report*. Retrieved from ise.fraunhofer: http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report.pdf

Technology	**On-Farm Devices for Precision Irrigation**
Short Description	
 *Data Collection Node for Precision Irrigation [1]*	Climatic and soil-water status monitoring devices (e.g. soil tensiometer, ambient temperature sensor, pressure transducer) can be integrated within an irrigation system in order to support farmers, through the provision of environmental data, in conducting irrigation, based on precision scheduling. This method has a significant potential to optimize the water use efficiency, reduce associated costs and minimize the energy input requirement, while enhancing the crop yield. The main precision irrigation technologies are divided into two categories, the first is responsible for gathering environmental data (locally installed sensors or regional meteorological information) and the second is a wireless networking infrastructure (e.g. communication networks, routers, gateways and switching hubs), responsible for the control and optimization of the system [1,2].
General Information	
Sector	Agricultural water systems
Stage	Water use (on-farm cropped plots)
Economic Data	
Technology Lifetime	5-10 years [3]
Investment Cost	500-2,000 €/ha [3]; payback period: 5-20 years (application in dairy and cropping in New Zealand) [4]
Operation Cost	200 €/ha (0.18 €/m3, average annual cost) [3]
Environmental Performance	
Water saving	Average water savings vary in the range: 8-20% (according to case studies) [4]
Energy efficiency	15-50% reduction in energy use (utilization of the AgriMet technology) [1].
Physical efficiency	Water use efficiency can reach 80-90% [4]
Environmental impacts	Reduction in energy consumption, water use efficiency improvement, advance crop yield and reduce farm runoff (major source of water pollution) [1]
Applications/Innovative Character	
Investigation of precision irrigation technologies in the entire state of California concluded in: 2 billion kWh energy savings and 1.2 million metric tons reductions in CO_2 emissions per year [1] Wireless Irrigation Network (WIN) for precision irrigation, Pajaro Valley, CA, USA [2] Wireless Sensor Network (WSN) for estimation of crop water needs, Sula vineyard, Nashik, India [5]	
References	
[1]	Marks, G. (2010). Precision Irrigation, A Method to Save Water and Energy While Increasing Crop Yield, A Targeted Approach for California Agriculture. Fremont, California.
[2]	ECOFARM. (2013, July 03). Precision Irrigation. Retrieved from The Water Stewardship Project: http://agwater.wordpress.com/precision-irrigation
[3]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No: Master Deliverable, November 2013)
[4]	Smith, R. J., Baillie, J. N., McCarthy, A. C., Raine, S. R. and Baillie, C. P. (2010). Review of Precision Irrigation Technologies and their Application. Project Report. National Centre for Engineering and Agriculture, Toowoomba, Australia.
[5]	Shah, N. G., and Ipsita Das (2012). Precision Irrigation: Sensor Network Based Irrigation, In Kumar, M. (Ed.) Problems, Perspectives and Challenges of Agricultural Water Management, InTech.

Technology	**Sub-surface Drip Irrigation (SDI)**
Short Description	
 *Subsurface drip irrigation in vineyard [1]*	Subsurface drip irrigation (SDI) is a variation of the conventional surface drip irrigation. SDI systems supply water to crops through buried plastic drip lines with emission points that deliver water underground at a depth where most of the rooting system reside. The top soil and the canopy are kept dry, thus reducing weed growth as well as water losses by soil evaporation and surface runoff.
General Information	
Sector	Agricultural water systems
Stage	Water use (on-farm, cropped plots)
Economic Data	
Technology Lifetime	15-20 years [2]
Investment Cost	5,000 €/ha [2]
Operation Cost	0.06 Euro/m^3 [2]
Environmental Performance	
Water saving	15-45% compared to surface irrigation, depending on irrigated crops and irrigation depth [3,4]
Energy efficiency	-
Physical efficiency	Greater crop yield [3]
Environmental impacts	
Applications/Innovative Character	
Sugar beet - Experimental field in Greece [3] Maize production in semi arid climates - Field study in Tunisia [4] Tomato, sweet corn, cotton and cantaloupe - Field study in California, USA [5]	
References	
[1] Riego subterráneo en viña. (2013, May 14) Retrieved from VitiViniCultura: http://www.vitivinicultura.net/2011/07/riego-subterraneo-en-vina.html [2] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No: Master Deliverable, November 2013) [3] Sakellariou-Makrantonaki, M., Kalfoutzos, D. and Vyrlas, P. (2002). Water saving and yield increase of sugar beet with subsurface drip irrigation. *Global Nest*: the Int. J. 4, 85-91. [4] Douth, B. and Boujelben, A. (2011). Improving Water Use Efficiency for a Sustainable Productivity of Agricultural Systems Using Subsurface Drip Irrigation. *Journal of Agricultural Science and Technology* B1, 881-888. [5] Ayars, J.E., Phene, C.J., Hutmacher, R.B., Davis, K.R., Schoneman, R.A., Vail, S.S. and Mead, R.M. (1999). Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. *Agricultural Water Management*, 42, 1-27.	

Technology	**Shifting of Irrigation Methods**
Short Description	
 *Drip Irrigation, Increasing Water Efficiency and Crop Yield [1]*	By changing the irrigation method from sprinkle to mini-sprinkle and from mini-sprinkle to drip-irrigation, water and energy savings can be achieved through reducing the water input and pressure requirements. Sprinkle irrigation is the method by which pressurized water is ejected through the nozzle of the sprinkler-device and it is sprayed on the land in the form of artificial rain. Small sprinkler heads can operate at low pressures/flow conditions and are suitable when a small radius of throw is required (mini-sprinklers operate at flow rates between 150-300 l/h) [1]. On the other hand, drip irrigation systems (surface or sub-surface) utilize a number of point sources for the slow and precise application of water/nutrients directly to the root zones in a controlled flow/pattern that satisfies the peak crop water requirements [2]. This latter method results in great water savings because of several reasons such as the high application uniformity (~90%), provision of the exact amount required and elimination of losses due to the wind [3].
General Information	
Sector	Agricultural water systems
Stage	Water use (on-farm cropped plots)
Economic Data	
Technology Lifetime	15-20 years [4]
Investment Cost	4,000 €/ha (average investment cost)[4]
Operation Cost	0.048 € /m^3 [4]
Environmental Performance	
Water saving	15-55 % water saving increase [5]
Energy efficiency	-
Physical efficiency	90% (drip irrigation efficiency);65-75% (sprinkler irrigation efficiency); 80% (micro-sprinkler irrigation efficiency); 18-50 % yield increase [5]
Environmental impacts	Water saving; reduced energy consumption; reduced drainage hazards; increased land utilization and less off-site impact of nutrients [5]
Applications/Innovative Character	
Corn and soybean farm, switched to drip irrigation and achieved $160/acre reduced costs due to reduced use of fuel, chemicals, fertilizers, labor and cultivation expenses – Nebraska, USA [6]	
References	
[1] IDE, International Development Enterprises. (2013, July 02). *Sprinkle Irrigation System, Guidelines for Installation and Operation.* Retrieved from IDE web site: http://www.ideorg.org/ourtechnologies/sprinkler_guidelines.pdf [2] Ashraf, D. M. (2013, July 03). *Design of Drip Irrigation System.* Retrieved from pec: http://www.pec.org.pk/sCourse_files/DDIS/Lectures/Design%20of%20Drip%20Irrigation%20System.pdf [3] Dripirrigation. (2013, July 02). *Conserving Water with Drip Irrigation*. Retrieved from dripirrigation: http://www.dripirrigation.org/conserving_water.html [4] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [5] Irrigation Australia. (2006). Drip Irrigation, Increasing water efficiency and crop yield. *7th International Micro Irrigation Congress* (pp. 812-824). Kuala Lumpur, Malaysia: Irrigation Australia. [6] Drip Irrigation. (2013, July 02). *Financial Benefits of Drip Irrigation*. Retrieved from DripIrrigation: http://dripirrigation.org/financial_benefits.html	

Technology	**Variable Rate Irrigation (VRI)**
Short Description	
 *VRI Zone Control, Image from Prescription Software (One block is one management zone) [2]*	The VRI can be incorporated in an irrigation system to optimize the irrigation process by enabling the adaptation to climate variability and enhancing the resource-use efficiency. It is a modern agricultural management concept, consisting of hardware and software, allowing the continuous irrigation rate adjustment on individual management zones within the field [1]; it can be proven to be very effective in fields with several soil types and non-uniform topography [2]. It consists of: electronically/hydraulically/pneumatically activated valves, controller(s) for the activation and regulation of sprinklers, a motor controller regulating the flow rate, a GPS and a user interface through which field mapping and system set up can be carried out. This system reduces climate risks through excluding non-cropped (or marginal) areas from water application, reducing the flow rate in both low-lying areas and soils with higher water-holding capacity [1].
General Information	
Sector	Agricultural water systems
Stage	Water use
Economic Data	
Technology Lifetime	-
Investment Cost	5,000 – 30,000 € (depending on the size of the center pivot system/number of controlled sprinklers) [1]
Operation Cost	Lower pumping costs (15-20% [3]), weed-management costs in non-cropped areas (water and nutrients no longer applied) and fertilizer costs [1].
Environmental Performance	
Water saving	8-20% average reductions in water use compared to uniform irrigation processes (depending on field variability) [1]
Energy efficiency	5.6% energy savings (in the first operational season) resulting in 27-77 kg CO_2-eq/ha/yr reductions [3]
Physical efficiency	-
Environmental impacts	Water saving [1], reduction of fertilizers/chemicals consumption [4], increase in crop yield, less leaching and runoff of nutrients, reduction of weed and disease problems, less energy-related CO_2 emissions [1]
Applications/Innovative Character	
Dairy pasture and corn VRI fields, 20% reduction in CO_2 – equivalents emissions – New Zealand [1]	
References	
[1] Perry, C., Fraisse, C. W. and Dourte, D. (2012). *Agricultural Management Options for Climate Variability and Change: Variable-Rate Irrigation.* Florida: Department of Agricultural and Biological Engineering, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida (http://edis.ifas.ufl.edu/pdffiles/AE/AE48700.pdf). [2] Valley. (2013, July 04). *Controls, Variable Rate Irrigation*. Retrieved from Valleyirrigation: http://www.valleyirrigation.com/page.aspx?id=2342 [3] Grafton Irrigation Solutions. (2013, July 04). *Profitable Farming with Variable Rate Irrigation (VRI), Energy and Water Savings with VRI*. Retrieved from Graftonirrigation: http://www.graftonirrigation.co.nz/zimmatic/variable-rate-irrigation [4] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)	

Technology	**Regulated Deficit Irrigation (RDI)**
Short Description	
 *RDI in wine grapes [2]*	Regulated Deficit Irrigation (RDI) consists of inducing mild to moderate plant water deficits during specific phenological stages by withholding irrigation or by applying less water than plants would use under normal conditions, with the aim of reducing vegetative growth and to improve qualitative aspects of crop production. Using RDI commercially to control vegetative growth requires an understanding of concomitant changes in crop maturity, quality and storage life [1].
General Information	
Sector	Agricultural water systems
Stage	Water use (on-farm, cropped plots)
Economic Data	
Technology Lifetime	-
Investment Cost	-
Operation Cost	-
Environmental Performance	
Water saving	Less water consumption than in the case of full irrigation by 20-40% [1,3]
Energy efficiency	-
Physical efficiency	Crop yields depend on water deficits levels [1,2,4]
Environmental impacts	-
Applications/Innovative Character	
Apple trees – Experimental field at Washington State Univ. Prosser [1] Vineyards – Experimental field in New Zealand (2001-2003) [2]	

References

[1] Ebel, R.C., Proebsting, E.L. and Patterson, M.E. (1993). Regulated Deficit Irrigation May Alter Apple Maturity, Quality, and Storage Life. *HortScience*, 28 (2), 141-143.

[2] Irrigated Crop Management Service (ICMS) – Rural Solutions SA. (2013, July 1). Retrieved from PIRSA website: http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/39584/Regulated_Deficit_Irrigation_Strategies_in_Winegrapes.pdf

[3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[4] Greven, M., Green, S., Neal, S., Clothier, B., Neal, M., Dryden, G. and Davidson, P. (2005). Regulated Deficit Irrigation (RDI) to save water and improve Sauvignon Blanc quality? *Water Science and Technology*, 51 (1), 9-17.

[5] Fereres, E. and Soriano, M.A. (2006). Deficit irrigation for reducing agricultural water use. *Experimental Botany*, 58 (2), 147-159.

Technology	**Super-high density production**

Short Description

Olive trees in California Central Valley [2]

Shifting from high density orchards (between 200 and 400 trees/ha) to super-high density orchards (between 1200 and 2000 trees/ha) is expected to guarantee a production increase. However it also implies an increase of input resources needs. Moreover, farmers' decision for a new investment based in one system or the other is related with the capacity of investment, yield targets and the soil variability and quality [1].

General Information

Sector	Agricultural water systems
Stage	Water use

Economic Data

Technology Lifetime	-
Investment Cost	Depending on variety, tree size and quality purchased [2]
Operation Cost	-

Environmental Performance

Water saving	-
Energy efficiency	-
Physical efficiency	Increase in yield per acre [3]
Environmental impacts	Increase of the relation production/ water use; Possible degradation of soil and water quality due to the increase of input resources needs

Applications/Innovative Character

Super-high density olive orchard producing olives for oil, Sacramento Valley, CA, USA [2]
Experimental olive orchards, Valenzano, Bari, Italy, 2006 [3]
High density almond orchards, "Pantanello" experimental field station, Basilicata region, Italy [4]

References

[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[2] Vossen, P. M., Conell, J. H., Krueger, W. H., Klonsky, K. M. and Livingston, P. (2007). *Sample costs to establish a super-high density toolive orchard and produce olive oil*. University of California, Cooperative Extension. (2013, May) Retrieved from: http://ucce.ucdavis.edu/files/datastore/391-517.pdf.

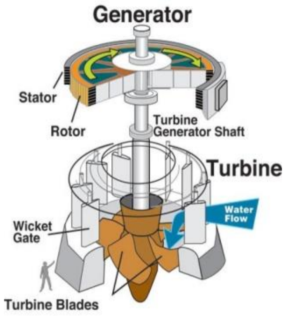
[3] Godini, A., Vivaldi, G. A. and Camposeo, S. (2011).Olive cultivars field-tested in super-high-density system in southern Italy. *California Agriculture*, 65(1), 39-40.

[4] Chiarotti, A., Martelli, G. and Monastra, F. (1998). Economic advantages of high-density planting of almond orchards. *X GREMPA Seminar* (pp. 81-85). Zaragaza: CIHEAM (Cahiers Options Méditerranéennes; n.33).

Technology	**Biological Production**
Short Description	
 *Biologically integrated orchard system [3]*	The shift from traditional agricultural production methods to modern biological production methods would obligate the utilization of natural agricultural enhancers, the conservation of natural resources, the maintenance of biodiversity and the preservation of the ecosystem. Organic agriculture is believed to produce significant social, economic and environmental benefits [1]; more specifically, the aim of such a practice is to improve the environmental impact, the quality of the products and the process effectiveness through enhancing water use efficiency and reducing the use of synthetic fertilizers (fertirrigation), pesticides and herbicides [2].
General Information	
Sector	Agricultural water systems
Stage	Water use
Economic Data	
Technology Lifetime	-
Investment Cost	-
Operation Cost	-
Environmental Performance	
Water saving	-
Energy efficiency	-
Physical efficiency	-
Environmental impacts	Reduction of water consumption, preservation of biodiversity (flora and fauna), promotion of animal/plant health, mitigation of desertification, reduction of soil/water pollution and CO_2/NO_2 (48-66% CO_2 reductions compared to conventional practices) [1]
Applications/Innovative Character	
6.3 million ha are under certified organic management (3.9% of total agricultural area), 13 billion € retail sales (2005) – European Union [1] Biologically integrated farming systems, California, USA, 1993-2000 [3]	
References	
[1] Morgera, E., Caro, C.B. and Durán, G.M. (2012). *Organic Agriculture and the Law.* Rome: Food and Agriculture Organization of the United Nations. [2] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [3] Swezey, S. and Broome, J. (2000). Growth predicted in biologically integrated and organic farming. *California Agriculture*, 54(4), 26-35.	

Technology	**Pressure Reducing Valve (PRV Control)**
Short Description	
 *VAG's Pressure Management Modular System [2]*	The purpose of this mechanism is to assist a given system to operate within a preset pressure range and therefore, optimize the water conservation; pressure control can reduce water losses due to leakages and water use can be decreased due to the lower pressure. An individual control system that regulates the pressure and flow of water can be set up, which would protect the pipelines and pumps from high internal stresses that initiate water losses due to leakages. Additionally, a successful control would enhance the energy and waste water savings [1].
General Information	
Sector	Urban water systems
Stage	Distribution Networks and Reservoirs
Economic Data	
Technology Lifetime	5 years (lifetime of battery) [3]
Investment Cost	100 – 2,500 € per item, depending on pipe dimensions and operational pressure range [4]
Operation Cost	
Environmental Performance	
Water saving	Minimization of excess pressure and water leakages/bursts; hence water loss and associated feed-in quantity is reduced [5]
Energy efficiency	Less water flows through the system, thus, less energy is required to heat the domestic water load [1]
Physical efficiency	-
Environmental impacts	-
Applications/Innovative Character	
VAG Industrial Pressure Reducing Valves Testing Tracks – Blansko, Czech Republic [6]	
References	
[1]	Watts. (2013, June 14). *Water Safety and Flow Control*. Retrieved from Watts - Plumbing, Heating and Water Quality Products Manufacturer: http://www.watts.com/pages/learnabout/reducingvalves.asp
[2]	VAG. (2013, June 14). *Pressure Management - VAG Solution - Modular System*. Retrieved from VAG - Valves: http://www.vag-armaturen.com/en/application-fields/pressure-management/vag-solution/modular-system.html
[3]	i20 Water Ltd. (2013, June 14). *i20 PRV System Technical Brochure.* Retrieved from i20 IntelligentWaterControl: http://www.i2owater.com/wpcontent/uploads/2012/06/TB-LV.pdf
[4]	RWC. (2013, June 14). *Trade Pricelist.* Retrieved from Reliance Water Control: http://www.relianceworldwide.com.au/download/CurrentPriceList.pdf
[5]	VAG. (2013, June 14). *Customer Benefits - Reduction of Water Loss*. Retrieved from VAG - Valves: http://www.vag-armaturen.com/en/application-fields/pressure-management/customer-benefits/reduction-of-water-loss.html
[6]	VAG . (2013, June 14). *Testing Room at CKD Blansko.* Retrieved from VAG - Valves: http://www.vag-armaturen.com/uploads/tx_news/Ref-pro_CKD-Blansko_edition1_11-01-13_EN.pdff

Technology	**Smart Pumping System**
Short Description	
 *Smart Pump System-Building Services [2]*	A smart pumping system consists of a pump mechanism (any standard centrifugal), variable speed drive, instrumentation, microprocessor and special software. All the pump-hydraulic characteristics, fluid characteristics, user control parameters and alarm settings are controlled; the pump output is effectively matched to the system head requirement and any threatening operating condition can be detected and the system automatically safeguarded. Therefore, a great value is created by the reduction of life cycle costs (e.g. maintenance, operating costs) [1].
General Information	
Sector	Urban water systems
Stage	Distribution Networks and Reservoirs
Economic Data	
Technology Lifetime	15 years [1]
Investment Cost	Since the flow rate is automatically regulated to suit the required system conditions, only one impeller diameter needs to be stocked~40,000€ (incl. installation costs) (refinery application) [1].
Operation Cost	The system would operate at substantially lower flow rate and head, the issue of utilizing an oversized pump and motor system is diminished resulting in lower operating costs. Because of the eliminated requirement of energy consuming valves, overall consumption would be reduced [1].
Environmental Performance	
Water saving	-
Energy efficiency	Up to 50 % reduction in energy consumption due to constantly operating near/ at the most efficient flow [1] In the application of a cooling tower, this system resulted in 251,300 kW/hr reduction in annual energy consumption [1]
Physical efficiency	-
Environmental impacts	-
Applications/Innovative Character	
Investigation of smart pumping system in a cooling tower installation – 35.5% and 33.5% reductions in operating and maintenance costs respectively, over the life of a pump [1].	
References	
[1] Stavale, A. E. (2001). Smart Pumping Systems: The Time is Now. *Canadian International Petroleum Conference, Jun 12 - 14, 2001, Calgary, Alberta.* Seneca Falls, NY USA: Society of Petroleum Engineers [successor to Petroleum Society of Canada]. [2] Pumpman. (2013, June 17). *Case Studies*. Retrieved from Pumpman, Pump System Specialists: http://www.pumpman.com/case-studies.htm	

Technology	**Hydropower Generator functioning as a pressure reduction valve**
Short Description	
 *Kaplan Turbine [2]*	The implementation of a number of hydropower sub-systems within a water supply system is considered to be a multipurpose plan. Water would not be consumed by the process and thus the distribution towards domestic, industrial and municipal facilities would be unaffected [1]. Moreover, this process would function as a pressure reduction valve (PRV), aiming at regulating the flow and the pressure of water so as to eliminate water losses created by leakages. The most effective locations on the total system are the water supply lines before the distribution network or the water treatment. The generated electricity can be used on site, exported to the grid or stored into batteries for future usage [3].
General Information	
Sector	Urban water systems
Stage	Distribution network
Economic Data	
Technology Lifetime	20 years [3]
Investment Cost	200,000 € [3]
Operation Cost	1.5-2.5% of investment cost per year [4]
Environmental Performance	
Water saving	Water losses reduction due to pressure reduction
Energy efficiency	-
Physical efficiency	-
Environmental impacts	Production of renewable “green power”
Applications/Innovative Character	
Difgen® hydropower generator, flow control of water entering the treatment process – Welsh and Devon WTPs, UK [5] Francis turbine as a PRV - water supply system, Logan, Utah, USA [6]	
References	
[1] Kumar, A., Schei, T., Ahenkorah, A., Caceres Rodriguez, R., Devernay, J.-M., Freitas, M., Hall, D., Killingtveit, A. and Liu, Z. (2011). *Hydropower*. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. [2] Newmills Engineering Ltd. (2013, June 21). *Our Products - Kaplan Turbines*. Retrieved from nemillsengineering: http://newmillsengineering.com/products/item/4/kaplan-turbines [3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [4] International Energy Agency. (2010). *Energy Technology Systems Analysis Program (ETSAP) - Hydropower.* International Energy Agency. [5] Zeropex. (2013, July 3). *The Difgen Case Studies*. Retrieved from Zeropex wabsite: http://www.zeropex.no/en/products/case-studies [6] Canyon Hydro (2013, July 3). *Special Hydropower Applications.* Retrieved from Canyon web site: http://www.canyonhydro.com/projects/conduit.html	

Technology	**Solar Water Heating**
Short Description	
 *Flat-Plate Solar Collector Array Support Structure [2]*	It is a domestic, energy saving solution that utilizes solar energy to heat water. The heating process is carried out either directly or through a heat transfer fluid. The technology consists of a collector, within which the fluid is heated and a storage tank, along with control and safety equipment. Furthermore, a number of prototypes include an electric pump, to circulate the fluid through the collectors and a back-up heater to satisfy the consumer's, hot water needs during periods of insufficient sunshine. The most common collector designs are the: (i) Flat-Plate, (ii) Evacuated Tube and (iii) Concentrating Collector. The first one is an insulated panel that contains a dark absorber plate, covered with a translucent or transparent material. Several rows of glass tubes are incorporated in the Evacuated-Tube design, each one consisting of a glass outer tube and an absorber (inner tube) on which a specific coating is applied (high-efficiency absorbance of solar energy and a low degree of radiative heat loss). Sun's energy is concentrated in the third concept on the 'receiver' (absorber tube) through a number of mirrored surfaces, located on a parabolic trough [1, 2].
General Information	
Sector	Urban water systems
Stage	Water use
Economic Data	
Technology Lifetime	20 years [3]
Investment Cost	1,850 € [3]
Operation Cost	1.59 €/m^3 [3]
Environmental Performance	
Water saving	-
Energy efficiency	Solar Energy Factor: 0.5-0.75, Solar Fraction: 0.0-1.0 [4]
Physical efficiency	-
Environmental impacts	No air-pollution or generation of waste; Reduction of CO_2, NO_X and SO_2 emissions [1]
Applications/Innovative Character	
Domestic hot water; Industrial water heat; and Indoor/outdoor swimming pools [2]	

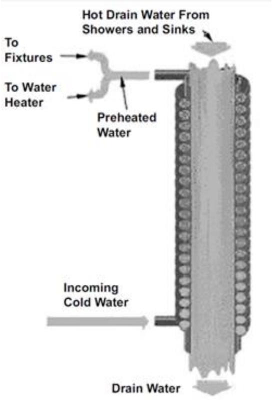
References

[1] National Renewable Energy Laboratory. (1996). *Solar Water Heating.* Retrieved from nrel: http://www.nrel.gov/docs/legosti/fy96/17459.pdf

[2] RETScreen® International Clean Energy Decision Support Centre. (2005). Clean Energy Project Analysis*: Retscreen® Engineering & Cases Textbook, Solar Water Heating Project Analysis Chapter.* Varennes: CANMET Energy Technology Centre

[3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[4] U.S. Department of Energy. (2012). *Estimating the Cost and Energy Efficiency of a Solar Water Heater*. Retrieved from Energy.gov: http://energy.gov/energysaver/articles/estimating-cost-and-energy-efficiency-solar-water-heater

Technology	**Heat recovery from wastewater**
Short Description	
 *Gravity –Film Heat Exchanger (GFX) [1]*	The wastewater originating from all hot water domestic and municipal applications (e.g. showers, sinks, dishwashers) retains a large percentage of the initial thermal energy [1]. The thermal energy can be transferred from the wastewater stream to a closed-pipe system, which contains a carrier fluid (water or refrigerant), through the means of a heat exchanger or a heat pump. This system is called District Energy System (DES) and transports heat for space and hot water heating purposes [2]. The Gravity-Film Heat Exchanger (GFX) is a reliable and simple design of a vertical counter-flow heat exchanger, consisting of a central copper pipe and multiple parallel coils enfolded on its outer wall surface. Thermal energy is directly transferred from the warm wastewater traveling within the central pipe to the cold input water, which simultaneously moves through the coils [1]. The effectiveness of the process is dependent on the wastewater temperature, flow rate, specific heat capacity and the heat transfer efficiency [2].
General Information	
Sector	Urban water systems
Stage	Water use
Economic Data	
Technology Lifetime	20 years [3]
Investment Cost	445 € [3]; payback period: 2- 3 years [1]
Operation Cost	Very low maintenance costs since the technology does not incorporate any moving parts [1]
Environmental Performance	
Water saving	-
Energy efficiency	30-50% reduction of the total energy required to heat showering water (experimental data for a wide range of operating temperatures); 800-2,300 kWh/year savings (utilized only for showering) [1]
Physical efficiency	-
Environmental impacts	Reduction of GHG emissions by depending less on fossil fuel energy [2]
Applications/Innovative Character	
Experimental analysis of a 60-inch GFX system, single-family household – Knoxville, Tennessee, USA [1]	

References

[1] Oak Ridge National Laboratory. (2001). *Heat Recovery from Wastewater Using Gravity-Film Heat Exchanger.* Medford, New York: U.S. Department of Energy (DOE).

[2] Johnston, C., Lindquist, E., Hart, J., Homenuke, M. (2009). *Four steps to recovering heat energy from wastewater.* Vancouver: BC Water and Waste Association.

[3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[4] Efficiency New Brunswick Corporation. (2013, July 09). *Drain Water Heat Recovery Systems.* Retrieved from efficiencynb: http://0801.nccdn.net/1_5/1a2/15a/12b/Drain-Water-Heat-Recovery-Systems.pdf

[5] Water Film Energy Inc. (2013, July 09). *GFX Models, Specs, Applications & Prices*. Retrieved from gfxtechnology: http://www.gfxtechnology.com

Technology	**Micro-pollutants Removal Technologies**
Short Description	
 *Sterling Vineyards Membrane Bioreactor Plant [4]*	Micropollutants (e.g. pesticides, pharmaceuticals) are toxic compounds originated from industrial sources and located in the aquatic environment. The removal of such substances within the wastewater treatment stage requires the utilization of sensors or biosensors along with an effective treatment method [1]. Membrane Bioreactors (MBRs) is an effective solution for the removal of soluble and particulate biodegradable materials and for the reclamation of urban wastewater. The utilization of this technology instead of a secondary clarifier in a Conventional Activated Sludge Process enables the accomplishment of enhanced sludge retention times (SRTs) in smaller treatment plant sizes and with reduced footprint. The separation of solids from the water is carried out through activated sludge treatment using Microfiltration (MF) or Ultrafiltration (UF) membranes [2, 3].
General Information	
Sector	Urban water systems
Stage	Wastewater treatment
Economic Data	
Technology Lifetime	Replacement of membrane every 5 years[4]
Investment Cost	225,000 – 450,000€ (application in the winery industry) [4]
Operation Cost	The cost of operating an MBR is higher than conventional WWTPs with secondary clarifiers due to high membrane replacement cost and high energy demand for aeration (10-15% increased energy costs than conventional). Membrane replacement cost is 37,500€ [3, 4].
Environmental Performance	
Water saving	The implementation of MBRs can initiate large volumes of water savings through water reuse.
Energy efficiency	Relatively greater consumption of energy than a conventional solution; for a high rate activated sludge treatment process the energy consumption varies from 60 to 150 HP/mgd [5].
Physical efficiency	Steroid removal rates greater than 90% are achieveable through the utilization of MBRs with nitrification and denitrification (SRT: 12-15 days) [2].
Environmental impacts	Effective removal of soluble and particulate biodegradable substances from environmental eco-systems [2].
Applications/Innovative Character	
Fowler Water Reclamation Facility (2.5 mgd treatment plant) – Forsyth County, Georgia, USA [5]	
References	
[1]	Virkutyte, J., Varma, R. S. and Jegatheesan, V. (2010). *Treatment of Micropollutants in Water and Wastewater.* London: IWA Publishing.
[2]	Rattier, M., Reutgoat, J., Gernjak, W. and Keller, J. (2012). *Organic Micropollutant Removal by Biological Activated Carbon Filtration: A Review.* Urban Water Security Research Alliance Technical Report No. 53..
[3]	Cinar, Ö., Hasar, H. and Kinaci, C. (2005). Modeling of submerged membrane bioreactor treating cheese whey wastewater by artificial neural network. *Biotechnology*, 123(2), 204-209.
[4]	Anu Shah, P.E., Summit Engineering, Inc. (n.d.). *Winery Wastewater treatment and Reuse: Membrane Bioreactor Technology.* Santa Rosa, California: Summit Engineering, Inc.
[5]	Cooper, N. B., Marshall, J. W., Hunt, K. and Reidy, J. G. (2006). *ENERGY USAGE AND CONTROL AT A MEMBRANE BIOREACTOR FACILITY.* Norcross, Georgia, USA: Water Environment Federation's Annual Technical Exhibition and Conference (WEFTEC).

Technology	Advanced Phosphorus Recovery Technologies

Short Description

Pearl 500 Technology Nansemond Waste Water Treatment Plan [3]

The global demand for phosphorus is considered to be rising and the expected high shortage in the near future reveals the importance of effective recovery; currently the main processes are categorized as either chemical or biological [1]. The high concentration of phosphorus in urban wastewater enables an effective utilization of recovery technologies that would have a dual role, to produce a large amount of a valuable substance and assist the prevention of eutrophication in the surface water where the effluents are discharged. The most effective technology is the magnesium ammonium phosphate (MAP) crystallization process; however, the implementation of the specific process requires either the removal or the deactivation of interfering metal ions. Alternative processes include the calcium phosphate crystallization and the utilization of active filters that employ slag materials [2].

General Information

Sector	Urban water systems
Stage	Waste water treatment

Economic Data

Technology Lifetime	
Investment Cost	Great costs associated with conventional phosphorus removal technologies are eliminated [4]
Operation Cost	Operation and maintenance costs are covered by the revenues of the fertilizer production [4]

Environmental Performance

Water saving	-
Energy efficiency	Chemical phosphorus removal has better energy efficiency than biological in terms of the aeration capacity of the process [1].
Physical efficiency	90% phosphorus and 10-15% nitrogen removal using the Pearl MAP technology to create struvite mineral pellets of 99.9% purity. This technology can simultaneously remove and recover both phosphorus and nitrogen [2, 4].
Environmental impacts	Recovery of a scarce and very valuable substance while enhancing the effluent quality on nitrogen and phosphorus.

Applications/Innovative Character

Gold Bar Wastewater Treatment Plan (700,000 people), since 2007 – Edmond, Canada [4]

Clean Water Services (500,000 people), since 2009– Tigard, Oregon, USA [4]

Nansemond Waste Water Treatment Plan (1.6 million people), since 2010 – Suffolk, Virginia, USA [4]

References

[1] Tanyi, A. O. (2006). *Comparison of Chemical and Biological Phosphorus Removal in Wastewater .* Lund, Scania, Sweden: Master Thesis, Institutionen för Kemiteknik.

[2] Bottini, A. and Rizzo, L. (2012). Phosphorus Recovery from Urban Wastewater Treatment Plant Sludge Liquor by Ion Exchange.*Seperation Science and Technology*, 47(4), 613-620.

[3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[4] Grontmij. (2013, June 25). *The Pearl Technology.* Retrieved fromgrontmij: http://grontmij.com/highlights/water-and-energy/Documents/The-Pearl-Technology.pdf

Technology	Natural Dyes

Short Description

Natural dyes [2]

Considering the toxic effects of the synthetic dyes there has been efforts to study and implement the various natural dyes in the textile industry. Primarily there are three categories of natural dyes: plant dyes (Indigo), animal dyes (Cochineal), and mineral dyes (Ocher). Natural Dyes can make textile industries more competitive, by reducing production costs and the huge expenses of chemical imports [1]. Their introduction into modern dyeing procedures can be seen as one step of a continuous development of textile dyeing and finishing processes towards increased sustainability with regard, to water, chemicals, and energy consumption [2]. Natural dyes are known for their use in colouring leather as well as natural fibres like wool, silk and cotton [3].

General Information

Sector	Industrial water systems
Stage	Water use

Economic Data

Technology Lifetime	-
Investment Cost	-
Operation Cost	About 40 €/kg of natural dyes [4]

Environmental Performance

Water saving	Water consumption is dependent on dyeing process
Energy efficiency	Consumption of energy comparable or lower than the current state-of-the-art systems based upon synthetic dyestuffs [3]
Physical efficiency	
Environmental impacts	Reduction of the use of toxics [1]

Applications/Innovative Character

“NATURALE”, dyes made with natural herbs, Tintoria di Quaregna, Biella, Italy [5]

References

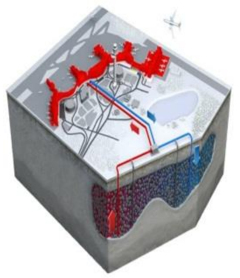
[1] *Natural Dyes*. (2013, July 8). Retrieved from Dyestuffs: http://dyes-pigments.standardcon.com/natural-dyes.html

[2] Samanta, A. K. and Konar A. (2011). Dyeing of Textiles with Natural Dyes, In Kumbasar E., A. (Ed.) *Natural Dyes*, InTech, Available from: http://www.intechopen.com/books/natural-dyes/dyeing-of-textiles-with-natural-dyes

[3] Bechthold, T., Turcanu, A., Ganglberger, E. and Geissler, S. (2003). Natural dyes in modern textile dyehouses-how to combine experiences of two centuries to meet the demandes of the future? *Cleaner Production*, 11(5), 499-509.

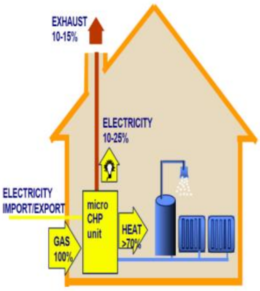
[4] Hill, D. J. (1997). Is ther s future for natiral dyes? *Review of Progress in Coloration and Related Topics*, 27(1), 18-25.

[5] *Tinture Naturali.* (2013, July 8). Retrieved from Tintoria di Quaregna: http://www.tintoriadiquaregna.it/naturali.html

Technology	**Thermal Energy Storage (TES)**
Short Description	
 *ATES – Aquifer Thermal Energy Storage (winter operation) [2]*	A wide variety of TES technologies effectively match energy demand and supply, when employed within buildings and industrial processes. Annual energy savings of 1.4 million GWh and decrease of 400 million tonnes of CO_2 emissions have been estimated through a more extensive utilization of TES systems in Europe. A widely used TES technology is the Aquifer Thermal Energy Storage (ATES), which uses a natural underground water-permeable layer as a storage medium and achieves a thermal energy transfer through extracting/re-injecting water from/into the aquifer. Effectively insulated water tanks are proved to be cost-effective TES solutions; however, major drawbacks associated with sensible heat storage applications include the variable discharging temperature and low energy density [1].
General Information	
Sector	Industrial water systems
Stage	Energy use
Economic Data	
Technology Lifetime	25 years [3]
Investment Cost	10,000,000 € [3]
Operation Cost	150,000 per year (maintenance cost) [3]
Environmental Performance	
Water saving	-
Energy efficiency	Storage efficiency: 50 – 90% (depending on the specific heat of the storage medium and the thermal insulation technology) [1]
Physical efficiency	60 kWh/m^3 energy density of water medium [4]
Environmental impacts	Improvement of water quality and biodiversity of the natural discharge water systems; Up to 65% decrease of CO_2 emissions, compared to a gas combustion heating source; Reduction of gas usage for heating. Unknown environmental impact of subsurface heating/heating of aquifers [3]
Applications/Innovative Characters	
TU Eindhoven, University campus, 32 hot & cold sources, capacity: 25 MW – The Netherlands [5] Shell Laboratory and 2,200 flats, 20MW Heat & 13MW Cold (including district heating) – Overhoeks, Amsterdam, The Netherlands [6]	
References	
[1] International Energy Agency . (2010). *Energy Technology Systems Analysis Program (ETSAP) - Hydropower.* International Energy Agency. [2] Underground Energy, LLC. (2013, July 10). *ATES - Aquifer Thermal Energy Storage*. Retrieved from underground-energy.com: http://www.underground-energy.com/ATES.html [3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [4] Faninger, G. (1998). *Thermal Energy Storage.* Klagenfurt: University of Klagenfurt [5] Technische Universiteit Eindhoven, University of Technology. (2013, July 10). *Aquifer Thermal Energy Storage (ATES)*. Retrieved from tue.nl: http://www.tue.nl/en/university/about-the-university/sustainability/corporate-social-responsibility/aquifer-thermal-energy-storage-ates [6] Honest Buildings. (2013, July 10). *Overhoeks Project*. Retrieved from honestbuildings.com: http://www.honestbuildings.com/projects/73857/overhoeks/#.Ud1Wi_lM-Al	

Technology	**Combined Heat and Power Production (CHP)**

Short Description



Schematic Diagram of a Domestic Micro CHP Unit [1]

Simultaneous production of electricity and heat can be carried out through the replacement of conventional gas central heating boilers with a single household Micro CHP unit. Part of electricity produced can be utilized by a householder in a range of 40-90% and the rest can be exported to the grid so as to be consumed by other consumers. The sale of export units has a lower value than the purchased electricity; hence, it is preferable to maximize the consumption of own production [1]. It can offer significant benefits to a householder (e.g. lower energy bills), to the energy supplier (e.g. enhanced profitability, customer retention) and to the society as whole (e.g. reduced GHG emissions) [1, 2]. Although it has been an underutilized technology for most countries in the past years, it currently represents more than 30% of the generating capacity of Denmark, Finland and the Netherlands [2].

General Information

Sector	Industrial water systems
Stage	Energy use

Economic Data

Technology Lifetime	10 years [3]
Investment Cost	11,000€ [3]
Operation Cost	0.65 €/m^3; 70 €/year (maintenance cost) [3]

Environmental Performance

Water saving	-
Energy efficiency	70-80% of the higher heating value (HHV) of the fuel is converted into heating & hot water services, 10-25% into electricity; the energy lost (flue gas) is 10-15%. The overall efficiency is at 90% (HHV) compared to 70-80% of a new boiler [1].
Physical efficiency	-
Environmental impacts	Reduction in CO_2 emissions compared to conventional electricity/heat production configurations [3].

Applications/Innovative Character

Dachs Micro-CHP, single, multi-family households, hotels, hospitals, etc – internal combustion engine with 5.5kW and 12.5kW output electricity and heat respectively [4]

References

[1] Harrison, J. and Redford, S. (2001). Domestic CHP: What are the Benefits? A scoping study to examine the benefits and impacts of domestic scale CHP in the UK. Capenhurst, England: EA Technology Ltd.

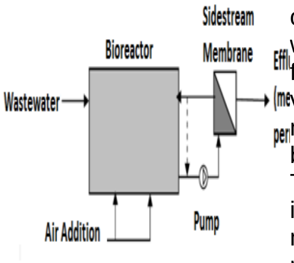
[2] U.S. Department of Energy. (2012). Combined Heat and Power, A Clean Energy Solution. Washington DC, USA: U.S. Department of Energy, United States Environmental Protection Agency.

[3] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[4] BDR Thermea. (2013, July 11). micro-CHP. Retrieved from bdrthermea.com: http://www.bdrthermea.com/micro-chp/

Technology	**Membrane Bioreactors (MBR)**

Short Description



Simplified Schematic Diagram of an External MBR Configuration [1]

A membrane biological reactor system is utilized for the treatment of organic/inorganic contaminants and microorganisms in industrial wastewater. It can operate at high contaminant volumetric removal rates and flows, while requiring no secondary clarifiers/filters and being compatible in very compact layouts [1, 2]. An MBR system consists of a combination of membrane units responsible for the separation of contaminants and biological reactor systems for the biodegradation of the waste compounds. The possible design configurations are: the external (side-stream) and the internal (submerged/immersed) configuration. Concerning the first one, a more direct hydrodynamic control of membrane fouling can be achieved, resulting in high operational fluxes and easier membrane replacement. The main disadvantages are the high energy consumption (2-12kWh/m^3) and the requirement of frequent cleaning. In the latter one the membranes are placed within the mixed fluid; less intensive operating conditions and much lower energy consumption are observed [3].

General Information

Sector	Industrial water systems
Stage	Secondary/Tertiary treatment

Economic Data

Technology Lifetime	3-7 years (membrane lifetime) [4]
Investment Cost	\$1,300–5,300 per m^3/day (equipment costs) [4]
Operation Cost	\$0.79–3.96 per m^3 of wastewater treated [4]

Environmental Performance

Water saving	Large volumes of water savings through water reuse.
Energy efficiency	Energy consumption: 0.2 - 2.4 kWh/m^3; the aeration process accounted for more than 80% [3]; anaerobic MBR (AnMBR) systems have higher energy efficiency [3].
Physical efficiency	-
Environmental impacts	Effective removal of particulate and dissolved pollutants; water reclamation and reuse; higher energy consumption compared to other biological treatment technologies but lower compared to thermal treatments [2, 4].

Applications/Innovative Character

Nestle, first large, full-scale internal MBR system installed in the U.S. for treatment of industrial wastewater, over 90% of nitrogen removal – New Milford, CT, USA. [1]

References

[1] Sutton, P. M. (2006). Membrane Bioreactors for Industrial Wastewater Treatment: Applicability and Selection of Optimal System Configuration. *Proceedings of the WEFTEC®*, (pp. 3233-3248).

[2] Cooper, N.B., Marshall, J.W., Hunt, K. and Reidy, J.G. (2006). Energy Usage and Control at a Membrane Bioreactor Facility. *Proceedings of the WEFTEC®,* (pp. 2518-2526)

[3] Lin, H., Gao, W., Meng, F., Liao, B.Q., Leung, K.T., Zhao, L., Chen, J. and Hong, H. (2012) Membrane Bioreactors for Industrial Wastewater Treatment: A Critical Review. *Critical Reviews in Environmental Science and Technology*, 42(7), 677-740. DOI: 10.1080/10643389.2010.526494

[4] Cheryan, M. and Rajagopalan, N. (1998). Membrane processing of oily streams. Wastewater treatment and waste reduction*. Journal of Membrane* Science, 151(1), 13-28.

Technology	**Ultrafiltration**
Short Description	
 *Industrial Duty UF Membrane for Wastewater Treatment [2]*	It is based on hydrostatic force for the mass transfer across the membrane. In cases of extensive pre-treatment requirements and/or great raw water quality fluctuations, an Integrated Membrane System (IMS) is designed, combining the UF pretreatment method (particle removal) prior to a Reverse Osmosis (RO) system. It simultaneously purifies, concentrates and fractionates macromolecules or fine colloidal suspensions. A UF membrane is applicable for particles and molecules that range from 1,000 (molecular weight) to 500,000 Daltons. The membrane material can be either organic (e.g. polymer) or inorganic; material selection is based on crucial properties for a given application (e.g. molecular weight, chain flexibility and interaction) and is significant for mechanical, thermal and chemical stability, while not affecting flux/rejection. The structure of these filters can be symmetric or asymmetric and a membrane in each of these categories can be either porous or non-porous [1].
General Information	
Sector	Industrial water systems
Stage	Tertiary treatment for discharge to sensitive recipients or water reuse
Economic Data	
Technology Lifetime	5 years (membrane lifetime) [3]
Investment Cost	60,000 – 130,000 € [4]
Operation Cost	0.5 kWh/m^3 (electricity) [4]
Environmental Performance	
Water saving	Water saving due to wastewater recovery
Energy efficiency	
Physical efficiency	Optimal recovery of feed water: 95-98% (dead-end filtration), 90-95% (cross-flow separation) [1]; up to 99% separation of emulgated oil and particles [4]; 90-100% removal of bacteria and viruses; increased RO flux up to 20% compared to conventional RO pre-treatment [1]
Environmental impacts	Improvement of the control of system fouling through the utilization of short-duration periodic backwashing, minimizing the chemical cleaning [1]
Applications - Experiments	
Yohuan Power Plant, Ultrafiltration of seawater for RO pre-treatment – Zhejiang Province, China [5]	
References	
[1] Wenten, I. G. and Ganesha, J. I. (2008). *Ultrafiltration in water treatment and its evaluation as pre-treatment for reverse osmosis system.* Bandung, Indonesia: Dept. of Chemical Engineering - Institut Teknologi Bandung. [2] Koch Membrane Systems. (2013, July 16). *ABCOR INDUCOR™ Series*. Retrieved from kochmembrane.com: http://www.kochmembrane.com/Membrane-Products/Tubular/Ultrafiltration/Abcor-INDUCOR-Series.aspx [3] Bick, A., Gillerman, L., Manor, Y. and Oron, G. (2012) Economic Assessment of an Integrated Membrane System for Secondary Effluent Polishing for Unrestricted Reuse. *Water*, 4, 219-236. [4] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [5] GE Water & Process Technologies. (2013, July 16). *Yuhuan Power Plant, CS.* Retrieved from gewater.com: http://www.gewater.com/pdf/Case%20Studies_Cust/Americas/English/CS_YUHU_INDPW_EN_1106_NA_GE_Logo.pdf	

Technology	**Reverse Osmosis (RO)**
Short Description	
 *Industrial Wastewater Reverse Osmosis, Siemens [2]*	It is a modern purification technology, producing water, suitable for a broad range of industrial applications that require demineralized or deionized water (e.g. power generation, pharmaceuticals) [1]. A pressure greater than the natural osmotic pressure (50 – 600 psig [2], depending on the concentration of contaminants in the input solution) is applied to the wastewater in order to drive it through a semi-permeable membrane barrier with a direction of high-to-low solute concentration and hence, obtain clean and recyclable water. The chemical potential of the water within the input solution is raised through this pressure and initiates a solvent flow towards the pure water side. However, a reject flow (brine) with a high concentration of contaminants would also be created, which could either go to drain or be recycled in the RO system so as to save water [1].
General Information	
Sector	Industrial water systems
Stage	Tertiary treatment for water reuse
Economic Data	
Technology Lifetime	3-7 years (Nanofiltration RO membranes) [3] 10-20 years (Equipment) [4]
Investment Cost	300,000 € (cost of a plant with a capacity of 1000 m^3/day) [5]
Operation Cost	40,000 € annual cost of membrane, 25,000 € annual cost of chemicals [5]
Environmental Performance	
Water saving	50-85% of wastewater can be recovered (directly related to the concentration factor, which drives the selection of membrane-type) [1, 2]
Energy efficiency	
Physical efficiency	95-99% of the contaminants are removed[1]
Environmental impacts	Water is saved by purifying and reusing industrial wastewater [1]
Applications/Innovative Character	
Two 30,000 gpd RO systems for water conservation and waste minimization, with minimal reject (8,000 gpd), Pfizer Pharmaceuticals, Fajardo, Puerto Rico [6]	

References

[1] Puretec. (2013, June 28). *Basics of Reverse Osmosis.* Retrieved from Puretec Reverse Osmosis Systems: http://puretecwater.com/resources/basics-of-reverse-osmosis.pdf.

[2] Siemens. (2013, June 28). *Industrial Wastewater Recycle/Reverse Osmosis Systems*. Retrieved from Siemens Water Technologies: http://www.water.siemens.com/en/products/membrane_filtration_separation/reverse_osmosis_systems_ro/Pages/Reverse_Osmosis.aspx

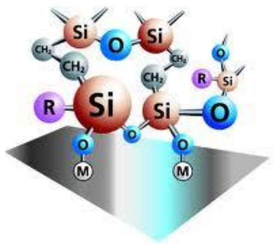
[3] United Nations Environment Programme Division of Technology, Industry and Innovations. (2013, June 28). *Reverse Osmosis Desalination (RO)*. Retrieved from Sourcebook of Alternative Technologies for Freshwater Augmentation in West Asia: http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8f/B/Desalination2.asp

[4] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[5] Ciardelli, G., Corsi, L. and Marcucci (2000). Membrane separation for wastewater reuse in the textile industry. *Resources, Conservation and Recycling*, 31, 189-197.

[6] Beca, J. (2007). Pharmaceutical discharge: Zero discharge for pharma plant. *Filtration & Separation*, 44(6), 40-1

Technology	**UV – Treatment**
Short Description	
 *Trojan UVSigma – Large – Scale Disinfection [2]*	The Ultra Violet (UV) disinfection is a mechanism responsible for the inactivation/destruction of harmful pathogenic microorganisms (e.g. bacteria, viruses, protozoa), found in industrial/domestic wastewater. Electromagnetic energy is transferred from a mercury arc lamp to the organism's genetic material and inactivates the ability of the cell to reproduce. The system incorporates a mercury arc lamp, a reactor (contact type or non-contact type) and a ballast (i.e. control box), whereas, the wavelengths and wall temperature of the lamp that correspond to the optimum operation of the treatment are in the range: 250 – 270nm and 95 – 122 ^{o}F respectively. Furthermore, the effectiveness the UV-Treatment is dependent on the characteristics of the wastewater (e.g. concentration of colloidal & particulate constituents), intensity of UV radiation, the radiation exposure time on the organism and the configuration of the reactor [1].
General Information	
Sector	Industrial water systems
Stage	Wastewater treatment
Economic Data	
Technology Lifetime	Average lamp life: 8,760 -14,000 hours Ballast lifetime: 10-15 years Quartz sleeves lifetime: 5-8 years [1]
Investment Cost	$244,000 (equipment: $120,000, structural modifications: $64,000, electrical: $20,000, miscellaneous: $40,000) [1]
Operation Cost	$19,190 annually (energy: $3300, lamps and chemicals:$2,840, cleaning: $1,180, maintenance: $1,440, process control: $6,240, testing: $4,160) [1]
Environmental Performance	
Water saving	Disinfection of secondary/tertiary treated wastewater for discharge or water reuse; the latter would result in water savings (amount depending on the waste water flow rate)
Energy efficiency	-
Physical efficiency	-
Environmental impacts	Low carbon footprint, no harmful residual effects [1]; No great increase in assailable organic carbon (AOC); Disposition of used lamps and/or obsolete equipment [3].
Applications/Innovative Character	
Gold Bar Wastewater Treatment Plan (average flow rate: 82 million gpd)– Edmond, Alberta, Canada [1] Northwest Bergen County Utility Authority Wastewater Treatment Plant (1989)– Waldwick, New Jersey, USA [1]	
References	
[1] ERA. (1999). *Wastewater Technology Fact Sheet Ultraviolet Disinfection.* Washington, D.C.: United States Environmental Protection Agency, Office of Water. [2] Trojan UV. (2013, June 28). *Products/Wastewater, TrojanUVSigma - Large - Scale Disinfection*. Retrieved from TROJANUV web site: http://trojanuv.com/products/wastewater/trojanuvsigna [3] National Drinking Water Clearinghouse. (2000). *Tech Brief Ultraviolet Disinfection* (Fact Sheet). West Virginia, USA: National Environmental Services Center (NESC).	

Technology	**Oxsilan®**
Short Description	
 *Oxsilan® [3]*	The Oxsilan® is the trademark for a silane based surface treatment chemical by Chemetall, which can be used as replacement of zinc-, manganese- and iron-phosphating and will provide paint bonding and corrosion protection [1]. This technology has been used successfully in a variety of industries for several years. In terms of quality, it is comparable to the zinc phosphating process, and with a view to its technical and economic feasibility, it is clearly advanced: lower process costs; higher productivity; multi-metal capability; and lower risk for safety, health and environment [2].
General Information	
Sector	Industrial water systems
Stage	Water use
Economic Data	
Technology Lifetime	-
Investment Cost	-
Operation Cost	-
Environmental Performance	
Water saving	Much less water than other methods [3] – 60% of water saving compared to traditional phosphating (zinc) technology [4]
Energy efficiency	Reduction of energy consumption by allowing processing to be done at ambient temperatures [3] – 77% of electrical energy & 42% of heating energy used for traditional phosphating (zinc) technology [5]
Physical efficiency	Increased productivity [3]
Environmental impacts	Water and energy saving, less solid waste [1]
Applications/Innovative Character	
Oxsilan 9820, Front and rear axles of Opel Insignia, Adam Opel GmbH, Germany, since 2009 [4]	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[2]	*Oxsilan*. (2013, July 9). Retrieved from Chemetall: http://www.chemetall.com/che/en/products/trademark/oxsilan_/oxsilan.jsp
[3]	*Chemetall's Oxsilan*. (2013, July 9). Retrieved from Cision: http://news.cision.com/chemetall/r/chemetall-s-oxsilan--pretreatment-provides-significant-energy-savings,c9145389
[4]	*Chemetall's Oxsilan*. (2013, July 9). Retrieved from http://www.ytteknik.com/resources/05-154_OXSILAN-Brosch-EN_24.pdf
[5]	Willumeit, T. (2013, July 9). Retrieved from imf: http://www.materialsfinishing.org/attach/CAT%20OXSILAN%20internet.pdf

Technology	**Carbon Filtration**

Short Description

Skid Mounted Multimedia Filters (TIGG Co.), Industrial Plant, Western Pennsylvania [3]

It is a water purification technology utilized for the removal of organic constituents, through chemical adsorption and of residual disinfectants through catalytic reduction. Besides the elimination of health hazards and the enhancement of water taste, it protects other water treatment units (e.g. reverse osmosis) from organic fouling or oxidation damages. The suitability of an activated carbon-type a given application depends on its surface properties [1]. Critical features of this mechanism include the high porosity of the activated carbon, the large surface area available for chemical reactions or adsorption and its ability to attract most organics even at low concentrations. The effectiveness of this method is influenced by a series of factors such as: pore size, chemical composition and concentration of the contaminate, content of O_2/H_2 within the activated carbon, temperature and pH of water and the flow rate or time exposure of water to the filter [1, 2].

General Information

Sector	Industrial water systems
Stage	Water treatment/Wastewater treatment

Economic Data

Technology Lifetime	15 years [4]
Investment Cost	
Operation Cost	

Environmental Performance

Water saving	Water savings through treated wastewater reuse
Energy efficiency	-
Physical efficiency	Less than 1.0 mg/l remaining substances [4]
Environmental impacts	Safe, remediated water back to the environment [3]

Applications/Innovative Character

Two pre-piped multi-media activated carbon filters (100 psig ASME Code), system automatically controlled through a programmable logic controller – Industrial Plant, Western Pennsylvania, USA [3]

References

[1] DeSilva, F. (2000). Activated Carbon Filtration. *Water Quality Products Magazine*.

[2] Singh, R. K., Vats, S. and Tyagi, P. (2011). Industrial Wastewater Treatment by Biological Activated Carbon- A Review. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* 2(4), 1053-1058.

[3] TIGG Corporation. (2013, July 15). *Activated Carbon Filtration, Industrial Water Filtration*. Retrieved from tigg.com: http://www.tigg.com/activated-carbon-filtration.html

[4] U.S. Department of Interion, Bureau of Reclamation. (2013, July 15). *Granular Activated Carbon (GAC).* Retrieved from Reclamation, Managing Water in the West: http://www.usbr.gov/pmts/water/publications/reportpdfs/Primer%20Files/07%20-%20Granular%20Activated%20Carbon.pdf

[5] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

Technology	Variable tariffs of water supply - demand
Short Description	
	Definition of variable price ranges for water supplied according to the volume of water uses. There is enough available data and knowledge to deliver decision support information about crop water needs. With this information each farmer, for each crop, soil and irrigation technology could have access to the recommended amount of water to apply. If more water is requested, a higher cubic meter price should be charged [1].
General Information	
Sector	Agricultural
Stage	Water Use
Economic Data	
Technology Lifetime	-
Investment Cost	-
Operation Cost	-
Environmental Performance	
Water saving	-
Energy efficiency	-
Physical efficiency	-
Environmental impacts	-
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

Technology	**Variable tariffs of water supply - energy**
Short Description	
	Definition of variable price ranges for water supplied, according to the correspondent schedule/ energy price of the time period of supply. The Monte Novo farmers association has the responsibility to deliver water at the conditions farmers contracted and that the supply system supports. Since farmers can request water at any time of the day or day of the year, it can represent variable levels of costs for farmers' association operation. With a variable price of supplied water, could be promoted, when and wherever possible, a preferable water supply during low energy tariffs periods [1].
General Information	
Sector	Agricultural
Stage	Water Use
Economic Data	
Technology Lifetime	-
Investment Cost	-
Operation Cost	-
Environmental Performance	
Water saving	-
Energy efficiency	-
Physical efficiency	-
Environmental impacts	-
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

Technology	**Alter current pressure head delivery**
Short Description	
	At this stage, the Monte Novo distribution irrigation network operates at different levels of pressure head in what regards water deliver to farmers. The distinction is made in high pressure levels (essentially for small to medium sized farms) enabling farmers to use this water volumes directly from distribution network, without any additional pumping station (but at higher water tariffs), and the low pressure levels (for larger farms) which implies that farmers invest and install their one pumping stations to ensure the pressure head levels required (compensated with lower water tariffs). At this stage is being discussed the possibility to change this distinction since the difference in water prices can be insufficient to compensate farmers from investing in their own pumping stations [1].
General Information	
Sector	Agricultural Sector
Stage	Water Distribution
Economic Data	
Technology Lifetime	-
Investment Cost	-
Operation Cost	-
Environmental Performance	
Water saving	-
Energy efficiency	-
Physical efficiency	-
Environmental impacts	-
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

Technology	**Solar sludge drying**
Short Description	
 *Solar Sludge Dryer [2]*	Solar sludge drying provides an economical solution to the sludge management problem and reduces the transportation, handling, and landfilling costs. It improves sludge appearance, facilitates handling and storage operations and Reduces the amount of sludge, limits transportation and treatment costs Sludge drying with solar energy. The general construction of a solar sludge dryer consists of a greenhouse equipped inside with drying fans. The greenhouse is made of transparent material (glass or polycarbonate plates) and a concrete floor, where the sludge is spread over the floor in thin layers. Depending on the raw sludge water content the floor might be equipped with a drainage system [7]
General Information	
Sector	Urban
Stage	WWTP
Economic Data	
Technology Lifetime	30 years [7]
Investment Cost	5,000,000 € for an installation serving a WWTP 1.1 million p.e., maximum flow to the treatment plant 297,000 m3/d and BOD5 50,000 kg/d approx. [5]
Operation Cost	
Environmental Performance	
Water saving	-
Energy efficiency	Minimizes thermal energy consumption [2] More than 50% energy savings [2]
Physical efficiency	-
Environmental impacts	The sludge to be disposed would be reduced by approximately 40% [4] Increases product dryness up to 90% dry solids [2]
Applications/Innovative Character	
Solar sludge dryer in Palma de Mallorca, with annual sludge quantity of 33,000 tons/year. [3] Several plants in France with capacity varying from 10,000-70,000 person-equivalents [6]	

References

[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[2] Parkson. (2013, November 29). *Activated Carbon Filtration, Industrial Water Filtration*. Retrieved from parkson.com: http://www.parkson.com/sites/default/files/documents/brochure_thermosystem_low_march_29_2011_0.pdf

[3] Parkson. (2013, November 29). *Energy efficient, solar sludge drying for large treatment facilities*. Retrieved from parkson.com: http://www.parkson.com/sites/default/files/documents/document-case-study-palma-de-mallorca-317.pdf

[4] Salihoglu, N.K., Pinarli, V., Salihoglu, G., (2007), *Solar drying in sludge management in Turkey*, Renewable Energy Volume 32, Issue 10, pp. 1661–1675.

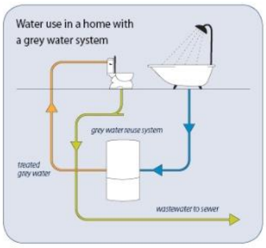
[5] Meyer-Scharenberg, U., Pöppke, M., (2010) *Large-scale Solar Sludge Drying in Managua /Nicaragua*, Water and Waste, pp. 26-27.

[6] Veolia. (2013, November 29). SOLIA™ *Greenhouse solar sludge drying*. Retrieved from: http://www.veoliawaterst.com/processes/lib/pdfs/productbrochures/key_technologies/EAA2tAijcqT1B7VO925t7iWR.pdf

[7] Hugi. C, Steiger, O., Niewersch, C., Ribarova, I., Stanchev, P. (2013). Deliverable 3.3: Innovative technologies for eco-efficiency improvement. EcoWater Project.

Technology	**Water reuse for domestic water users**

Short Description



Greywater Reuse System [4]

Water reuse systems for households are suitable to recycle the so-called greywater from domestic water users. Greywater means the wastewater from washing machines, showers, baths and washbasins. Wastewater from the toilet is referred to as black water and contains a significantly higher organic content than greywater [2].

The suitability of this stream to be included in a domestic water reuse system depends on the complexity of the treatment technology applied. If a biological treatment should be applied in the water reuse system including the kitchen grey water is beneficial for meeting the microbial nutrient requirements [3].

General Information

Sector	Urban Water System
Stage	Water Use

Economic Data

Technology Lifetime	20 years [1]
Investment Cost	**Capital cost for indicative alternative systems are [5]:** Filtration with nylon filter + sedimentation + disinfection with hypochlorite:195 €/household Sedimentation + silex anthracite filter + cartridge filter + sedimentation + disinfection with hypochlorite: 428 €/household Filtration with cylindrical sieve + oxygenation + disinfection with UV light: 1,018 €/household Oxygenation + Filtration with 20-µm-filter + disinfection with hypochlorite or UV light: 691 €/household
Operation Cost	-

Environmental Performance

Water saving	30-40% [Bello-Dambatta et al., 2012].
Energy efficiency	-
Physical efficiency	-
Environmental impacts	-

Applications/Innovative Character

References

[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[2] Bello-Dambatta, A.; Kapelan, Z.; Butler, D.; Oertle, E.; Hugi, C.; Jelinkova, Z.; Becker, N.; Hochstrat, R.; Rozos, E.; Makropoulos, C.; Wintgens, T. (2012) *Urban Water Demand Management – Milestone M42.1 – Priorities of Current and Emerging Water Demand Management Technologies and Approaches*. Report of Work Package 42 of the EU-project TRUST.

[3] Li, F.; Wichmann, K.; Otterpohl, R. (2009) *Review of the technological approaches for grey water treatment and reuses.* Science of the Total Environment 407, 3439-3449.

[4] City of Guelph (2013, December 02). Greywater Reuse System. Retrieved from: http://guelph.ca/living/environment/water/water-conservation/greywater-reuse-system/

[5] Domènech, L.; Saurí, D. (2010). *Socio-technical transitions in water scarcity contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona*. Resources, Conservation and Recycling, 55, 53-62.

Technology	**Water reuse for non-domestic water users**
Short Description	
 *Rainwater reuse system for car washing [3]*	The selection of suitable technologies for water reuse depends strongly on the characteristics of the wastewater to be reused and on the intended purpose. Some sectors as food production and beverage production will require the same quality standards as for usage as potable water. If water reuse is intended for these sectors, a comprehensive combination of treatment technologies has to be applied to achieve the criteria for unrestricted use. Other applications like cooling water, pulp and paper industry or rinsing water for commercial laundries require lower quality requirements. Furthermore there are applications for which the quality requirements are very high but different than for drinking water like boiler feed water [2].
General Information	
Sector	Urban Water System
Stage	Water Use
Economic Data	
Technology Lifetime	Varies depending on the application
Investment Cost	**Data for indicative alternative applications and treatment systems are [4]:** Water reuse for recreational uses as ponds: 9-22 €/(m^3/day) Water reuse for recreational uses as irrigation of golf fields: 28-48 €/(m^3/day) Refrigeration towers and evaporation condensers / Bathroom appliances (non-potable): 185-398 €/(m^3/day)
Operation Cost	**Data for indicative alternative applications and treatment systems are [4]:** Water reuse for recreational uses as ponds: 0.04-0.07 €/m^3 Water reuse for recreational uses as irrigation of golf fields: 0.06-0.09 €/m^3 Refrigeration towers and evaporation condensers / Bathroom appliances (non-potable): 0.14-0.2 €/m^3
Environmental Performance	
Water saving	Varies depending on the application
Energy efficiency	-
Physical efficiency	-
Environmental impacts	-
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[2]	Bixio, D.; Weemaes, M.; Thoeye, C.; Ravazzini, A.; Miska, V.; De Koning, J.; Cikurel, H.; Aharoni, A.; Muston, M.; Khan, S.; Dillon, P.; Schäfer, A.; Joksimovic, D.; Savic, D.; Wintgens, T.; Tings, A.; Kazner, C.; Lyko, S.; Melin, T.; Rousseau, D.; Lesage, E. (2006). *Water reuse system management manual*, Office for Official Publications of the European Communities, Luxembourg, ISBN 92-79-01934-1.
[3]	Stormsaver (2013, December 01), What rainwater harvesting system would suit me? Retrieved from: http://www.stormsaver.com/Commercial-System-Basics
[4]	Iglesias, R.; Ortega, E.; Batanero, G.; Quintas, L. (2010) *Water reuse in Spain: Data overview and sots estimation of suitable treatment trains*, Desalination, 263, 1-10.

Technology	**Water Saving Appliances**
Short Description	
 *Water Saving Appliances (Toilet, Showerhead, Dishwasher, Faucet) [3,4,5,6]*	There are several appliances that could achieve reductions in the consumption of water in households and while integrated within urban water systems, enhancements in the performance of the overall system would be observed. Examples of this type of technologies include: low flushing toilets, high efficiency shower heads, dishwashers and faucets. Some of these appliances could potentially be employed for non-domestic purposes as well.
General Information	
Sector	Urban water systems
Stage	Water use
Economic Data	
Technology Lifetime	10 years [1]
Investment Cost	$250-800 (toilet); $150-1,500 (showerhead) [2]; $170-1,750 (dishwasher) [3]; $800-1,300 (faucet) [2]
Operation Cost	0.51 €/m3 [1]
Environmental Performance	
Water saving	Compared to conventional appliances: At least 20% (toilet in the range: 1.28-5.5 gallons per flush) [5]; 30% through the utilization of a 1.75 GPM showerhead, assuming an average household of 3.2 people and a daily per capita utilization of 8min [6]; 20% (high efficiency dishwasher) [3]; 32% (faucet) - 0.17 gallons per 10 sec-cycle [7]
Energy efficiency	Annual Energy Savings: 123 kWh/person (showerhead), 125 kWh/person (faucet), 36 kWh/person (dishwasher) [4]
Physical efficiency	-
Environmental impacts	Reduction in energy and water consumption; minimal requirement for environmentally unfriendly toilet detergents [5]
Applications/Innovative Character	

References

[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[2] TOTO. (2013, July 05). *Products*. Retrieved from totousa: http://www.totousa.com/Products/Accessories.aspx

[3] Energy Star. (2013, July 05). *Dishwashers, 2007 Partner Resource Guide*. Retrieved from ó Innovation Performance Savings Energy Star® Makes It Simple.: http://www.energystar.gov/ia/partners/manuf_res/downloads/2007Dishwasher_prg.pdf

[4] The Pennsylvania State University. (2004). *Household Water Conservation.* Pennsylvania: Pennstate University, Cooperative Extension of Agricultural Sciences.

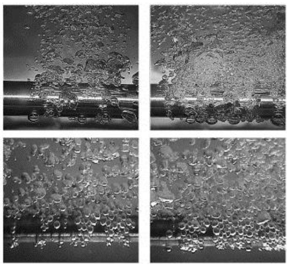
[5] TOTO. (2013, July 05). *Efficiency Without Sacrificing Performance, High Efficiency Toilet*. Retrieved from totousa: http://www.totousa.com/Green/Products/HighEfficiencyToilets.aspx

[6] TOTO. (2013, July 05). *High Efficiency Showers*. Retrieved from totousa: http://www.totousa.com/Green/Products/HighEfficiencyShowers.aspx

[7] TOTO. (2013, July 05). *Self_Sustaining*. Retrieved from totousa: http://www.totousa.com/Green/Products/EcoPowerFaucets.aspx

Technology	**Low Flow Toilet**
Short Description	
 *4 litre flush toilet [2]*	A low-flow toilet is a flush toilet that uses significantly less water than a full-flush toilet. Low-flow toilets use 4 to 6 liters (1 to 1.6 gallons) per flush as opposed to 13.2 liters that use the full-flush toilets. [2,3,4]
General Information	
Sector	Urban Water Systems
Stage	Domestic water use
Economic Data	
Technology Lifetime	20 years [1]
Investment Cost	€200-800 approximately [2,3,4]
Operation Cost	
Environmental Performance	
Water saving	60-70% compared to full-flush toilets [2,3,4]
Energy efficiency	
Physical efficiency	
Environmental impacts	
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[2]	TOTO. (2013, July 05). *Products*. Retrieved from totousa: http://www.totousa.com/Products/Accessories.aspx
[3]	American Standard (2013, November 29). Product Listing. Retrieved from: http://www.americanstandard-us.com/products/
[4]	Kohler US (2013, November 29). Products. Retrieved from: http://www.us.kohler.com/us/Toilets-Styles-of-Toilets/category/429984/429204.htm?page=categoryLanding

Technology	**Low-flow faucets/showerheads**
Short Description	
 *Low-flow showerhead [2]*	Low-flow faucets and showerheads use significantly less water than full-flow faucets and showerheads Low-flow faucets use approximately 6 liters water per minute and low-flow showerheads use 11 liters water per minute [5]
General Information	
Sector	Urban Water Systems
Stage	Domestic water use
Economic Data	
Technology Lifetime	20 years [1]
Investment Cost	€100-1,100 (showerhead), €600-1,000 (faucet) [2, 3, 4]
Operation Cost	
Environmental Performance	
Water saving	Up to 40% water savings [2, 3, 4, 5]
Energy efficiency	Annual savings in a family of 4 by using low flow appliances: 1,300 kWh of energy or 130 liters of heating oil [5]
Physical efficiency	
Environmental impacts	Annual savings in a family of 4 by using low flow appliances: approx. 400kg CO_2 from hot water [5]
Applications/Innovative Character	
References	
[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [2] TOTO. (2013, July 05). *Products*. Retrieved from totousa: http://www.totousa.com/Products/Accessories.aspx [3] American Standard (2013, November 29). Product Listing. Retrieved from: http://www.americanstandard-us.com/products/ [4] Kohler US (2013, November 29). Products. Retrieved from: http://www.us.kohler.com/us/Toilets-Styles-of-Toilets/category/429984/429204.htm?page=categoryLanding [5] AquaClic (2013, November 29). AquaClic ® Water Savers. Retrieved from: http://aquaclic.info/sparpotentialsh.php	

Technology	**Smart cooling of water with bubble screens**
Short Description	
 *Increasing heat transfer through bubble screens*	Reducing thermal discharge and thermal gradient in the ARC by applying bubble screens (for enlarging heat emission and water mixture) and pre-discharge mixture with unused ARC water (for reducing water temperature of the discharge) [1].
General Information	
Sector	Industrial Systems
Stage	Water Supply
Economic Data	
Technology Lifetime	15 years [1]
Investment Cost	5,000 € [1]
Operation Cost	500 €/year (maintenance cost) [1]
Environmental Performance	
Water saving	
Energy efficiency	
Physical efficiency	
Environmental impacts	
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

Technology	**Adaptive ratio of electrical and thermal energy production**
Short Description	
	Better matching energy demand and supply by adapting the ratio of Electrical and Thermal energy production [1].
General Information	
Sector	
Stage	
Economic Data	
Technology Lifetime	50 years [1]
Investment Cost	100,000 € [1]
Operation Cost	
Environmental Performance	
Water saving	
Energy efficiency	
Physical efficiency	
Environmental impacts	
Applications/Innovative Character	
References	
[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)	

Technology	Condenser for recovery of water from spray tower exhaust air
Short Description	
	Recovery of water from spray towers and/or flue gas [1].
General Information	
Sector	Industrial Water Systems
Stage	Water Use
Economic Data	
Technology Lifetime	
Investment Cost	
Operation Cost	
Environmental Performance	
Water saving	
Energy efficiency	
Physical efficiency	
Environmental impacts	
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

Technology	**Dissolved air flotation (with chemicals)**
Short Description	
 *Dissolved air flotation system for the Dairy Industry [2]*	Dissolved Air Flotation is widely used for separating solids, fats, oil, and grease from a waste stream. In the process, pressurized water is saturated with dissolved air and is discharged into a flotation vessel. The microscopic air bubbles attach to solids and float them to the surface, forming a sludge blanket. A scraping assembly skims the sludge off the surface of the water and into a sump. From the sump, sludge is pumped to dewatering equipment. The treated water flows from the DAF vessel for discharge or on to other treatment processes. [2]
General Information	
Sector	Industrial Water Systems
Stage	Wastewater Treatment
Economic Data	
Technology Lifetime	
Investment Cost	
Operation Cost	
Environmental Performance	
Water saving	
Energy efficiency	
Physical efficiency	
Environmental impacts	TSS reduction up to 99% and BOD reduction up to 75% [2]
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[2]	Ecologix Environmental Systems (2013, December 2). *Dissolved Air Flotation System*. Retrieved from: http://www.ecologixsystems.com/system-v-series-daf.php

Technology	**Activated sludge**
Short Description	
 *Adana West WWTP (250,000ªm/d) with an activated sludge process [2]*	Activated sludge is a biological process that utilizes microorganisms to convert organic and certain inorganic matter from wastewater into cell mass. The activated sludge is then separated from the liquid by clarification. The settled sludge is either returned (RAS) or wasted (WAS). Activated sludge is commonly used as a wastewater treatment process because it is an effective and versatile treatment process and capable of a high degree of treatment[1].
General Information	
Sector	Industrial Water Systems
Stage	Wastewater Treatment
Economic Data	
Technology Lifetime	
Investment Cost	
Operation Cost	
Environmental Performance	
Water saving	
Energy efficiency	
Physical efficiency	
Environmental impacts	
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[2]	Water Techhnology Net (2013, December 2). Operational Water Management Systems. Retrieved from : http://www.water-technology.net/contractors/wastewater/va-tech/va-tech3.html

Technology	**Anaerobic pre-treatment**
Short Description	
 *Anaerobic wastewater treatment in Ohio's largest cheese-producing facilities [2]*	Production of biogas based on organics from wastewater through anaerobic treatment prior to discharge to public sewer [1]. Anaerobic digestion is a complex multistep process in terms of chemistry and microbiology. Organic material is degraded to basic constituents, finally to methane gas under the absence of an electron acceptor such as oxygen. It is a technically simple and relatively inexpensive technology which consumes less energy, space and produces less excess sludge in comparison to the conventional aerobic treatment technologies. Net energy production from biogas makes the anaerobic treatment technology an attractive option over other treatment methods. [3]
General Information	
Sector	Industrial Water Systems
Stage	Wastewater Treatment
Economic Data	
Technology Lifetime	20 years [1]
Investment Cost	3,400,000 € [1]
Operation Cost	
Environmental Performance	
Water saving	
Energy efficiency	Methane Yield: 0.1-0.5 m^3 CH_4/kg COD [3]
Physical efficiency	Reduction of total sludge produced [3]
Environmental impacts	60%-90% COD removal [3]
Applications/Innovative Character	
References	

[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[2] Hazen and Sawyer (2013, December 2). Services in Industrial Wastewater. Retrieved from: http://www.hazenandsawyer.com/work/services/industrial-wastewater

[3] Evren Ersahin, M., Ozgun, H., Kaan Dereli, R. and Ozturk, I. (2011). *Anaerobic Treatment of Industrial Effluents: An Overview of Applications*. Waste Water - Treatment and Reutilization. Edited by Fernando Sebastián García Einschlag, ISBN 978-953-307-249-4

Technology	**Membrane distillation for incoming water**
Short Description	
 *Membrane distillation system [2}*	Membrane distillation (MD) is a process for production of very clean water [1]. It is a thermal, membrane-based separation process. The driving force for the MD processes is quite different from other membrane processes, being the vapor pressure difference across the membrane rather than an applied absolute pressure difference, a concentration gradient or an electrical potential gradient, which drives mass transfer through a membrane [3].
General Information	
Sector	Industrial Water Systems
Stage	Water Treatment
Economic Data	
Technology Lifetime	
Investment Cost	180,000 € for 3,5m^3/day (pilot equipment) [1]
Operation Cost	
Environmental Performance	
Water saving	
Energy efficiency	Increased energy consumption [3]
Physical efficiency	High quality of water produced (particularly if purified water is required as boiler feed) [3]
Environmental impacts	
Applications/Innovative Character	
References	
[1]	Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)
[2]	KTH (2013, December 1). The membrane distillation technology at Hammarby Sjöstadsverket in Sweden. Retrieved from http://www.kth.se/en/aktuellt/nyheter/tekniken-som-renar-avloppsvatten-fran-lakemedel-1.370072
[3]	Camacho, L.M., Dumée, L., Zhang, J., Li, J., Duke, M., Gomez, J., and Gray, S., (2013). *Advances in Membrane Distillation for Water Desalination and Purification Applications.* Water (5), pp. 94-196; doi:10.3390/w5010094

Technology	**Electrodialysis and Ion exchange (EDI)**
Short Description	
 *EDI System over 50 gpm [3]*	EDI is a combination of electrodialysis and ion exchange. It is used to produce very clean water. The ion-exchange resin is regenerated continuously by the direct current of the electrodialysis. However, the water needs pre-treatment [1]. The EDI process produces industrial process water of very high purity, using less than 95% of the chemical products used in the conventional ion exchange processes. With EDI system membranes and electricity replace the million gallons of acid and caustic chemicals that the old processes required daily. [2]
General Information	
Sector	Industrial Water Use
Stage	Water Treatment
Economic Data	
Technology Lifetime	
Investment Cost	
Operation Cost	Electricity replaces the chemicals required for regeneration [4]
Environmental Performance	
Water saving	
Energy efficiency	
Physical efficiency	95% less use of chemicals
Environmental impacts	No hazardous waste stream [4]
Applications/Innovative Character	

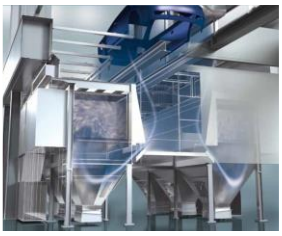
References

[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013)

[2] Lenntech (2013, December 1). Electrodeionization. Retrieved from http://www.lenntech.com/library/edi/edi.htm

[3] Agape Water Solutions Inc. (2013, December 1). Electrodeionization Systems. Retrieved from: http://www.agapewater.com/ElectrodeionizationSystems.htm

[4] GE (2013, December 1). E-Cell^{TM} Electrodeionization Systems. Retrieved from: http://www.gewater.com/products/electrodeionization-edi.htmll

Technology	**Dry filter instead of overspray in paint shop**
Short Description	
 *Eco Dry Scrubber [2]*	Instead of a water curtain catching overspray, the overspray is collected by ventilation and caught in a filter system [1]. Air, contaminated with paint particles during spraying, is sucked in and routed through the separation system. As it passes through the separation modules, paint particles are removed from the air [3].
General Information	
Sector	Industrial Water Systems (Automotive Industry)
Stage	Water Use
Economic Data	
Technology Lifetime	Equipment 10-20 years [1]. Ceramic filter material approx. 10 years [1].
Investment Cost	
Operation Cost	60% lower energy costs [3]
Environmental Performance	
Water saving	80% less water consumption compared to traditional wet separation systems [2]
Energy efficiency	>50% energy savings [2]
Physical efficiency	Requires no chemicals or additives [3]
Environmental impacts	No paint sludge, extremely low particle emissions and elimination of hazardous wastewater [2]
Applications/Innovative Character	
References	
[1] Nilsson, A (2013) Deliverable D1.3 for WP No 1, Task No 1.2, Technology inventory for eco-efficient water systems and use. Populated technology inventory (Version No.: Master Deliverable, November 2013) [2] Durr (2013, December 1). Eco Dry Scrubber. Retrieved from: http://www.durr.com/fileadmin/user_upload/fas/02_psa/pdf_e/EcoDryScrubber_Brochure_LowResolution_EN.pdf [3] Eisenmann (2013, December 1). Booth and separation systems. Retrieved from: http://www.eisenmann.com/en/products-and-services/automotive-systems-and-aerospace/paint-shops/booth-and-separation-systems.htmll	

EcoWater

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