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

Collaborative project, Grant Agreement No: 282882

Deliverable 6.6

Conference proceedings

January 2015

DOCUMENT INFORMATION

Project	
Project acronym:	EcoWater
Project full title:	Meso-level eco-efficiency indicators to assess technologies and their uptake in water use sectors
Grant agreement no.:	282882
Funding scheme:	Collaborative Project
Project start date:	01/11/2011
Project duration:	36 months
Call topic:	ENV.2011.3.1.9-2: Development of eco-efficiency meso-level indicators for technology assessment
Project web-site:	http://environ.chemeng.ntua.gr/ecowater
Document	
Deliverable number:	6.6
Deliverable title:	Conference proceedings
Due date of deliverable:	31 December 2014
Actual submission date:	20 January 2015
Editor(s):	Deltares
Author(s):	Deltares
Reviewer(s):	NTUA
Work Package no.:	6
Work Package title:	Dissemination, communication and science-policy links
Work Package Leader:	Michiel Blind, Deltares
Dissemination level:	Public
Version:	1.0
Draft/Final:	Final
No of pages (including cover):	124
Keywords:	N/A

Abstract

Deliverable 6.6 presents the results of the final scientific event, which took place in conjunction with "The Europe we want", 17th European Roundtable on Sustainable Consumption and Production, on the 14th to 16th October 2014 in Portoroz, Slovenia.

The EcoWater project participants successfully submitted and delivered 12 presentations at the Conference. Several of these products are being further developed into full papers. The abstracts and presentations are included in these proceedings. The draft full papers can be found via this link (https://conferences.matheo.si/getFile.py/access?resId=0&materialId=3&confId=0).

Contents

1 Introduction

The EcoWater project aims to achieve broad dissemination of its results. For this purpose, the Project team decided to combine the final scientific event with a relevant scientific conference, as this would attract a larger audience compared to a stand-alone conference. The chosen conference was “The Europe we want”, 17th European Roundtable on Sustainable Consumption and Production, which took place on the 14-16 October 2014 in Portoroz, Slovenia, and featured a total of 136 abstracts accepted for oral presentation.

#	Authors	Title	Publication
1	Assimacopoulos D., Angelis-Dimakis A. and Arampatzis G.	Systemic eco-efficiency assessment in water use systems	Full draft available, publication in 2015
2	Arampatzis G., Angelis-Dimakis A., Assimacopoulos D. and Blind M.	An online suite of tools to support the systemic eco-efficiency assessment in water use systems	Full draft available, publication in 2015
3	Levidow L.	Facilitating multi-stakeholder discussions on improvement options through comparative eco-efficiency assessments	Full draft available, publication in 2015
4	Todorovic M., Mehmeti A. and Scardigno A.	Assessing the eco-efficiency of a meso-scale agricultural water system in Southern Italy	Full draft available, publication in 2015
5	Maia R. and Silva C.	Eco-efficiency assessment in the agricultural sector: the Monto novo irrigation perimeter, Portugal	Full draft available, publication in 2015
6	Stanchev P., Dimova G., and Ribarova I.	Complexity, assumptions and solutions for eco-efficiency assessment of urban water systems	Full draft available, publication in 2015
7	Steiger O., Hugi Ch., Assimacopoulos D., and Levidow L.	Towards enhancing whole-system eco-efficiency: case study of a Swiss municipal water system	Intended 2015
8	Angelis-Dimakis A., Alexandratou A., and Balzarini A.	Value chain upgrading in a textile dyeing industry	Full draft available, publication in 2015
9	Blind M.	Improving resource and eco-efficiency of an electricity-heat cogeneration plant using a systemic eco-efficiency approach	Intended 2015
10	Lindgaard-Jørgensen P., Andersen M., and Holm Kristensen G.	Technology options in a dairy plant: assessing whole-system eco-efficiency	Full draft available, publication in 2015
11	Skenhall S,, Nilsson Å., Levidow L., Fortkamp U., Klingspor M. and Rydberg T.	Technology options in truck manufacturing: assessing whole-system eco-efficiency	Intended 2015

#	Authors	Title	Publication
12	Skenhall S., Danielsson L., and Rydberg T.	Comparing water footprint methods: the importance of a life cycle approach in assessing water footprint	Intended 2015

The conference proceedings including those papers denoted ‘full draft available’ in the table above, are available for via this link.

2 Abstracts and presentations

2.1 Systemic eco-efficiency assessment in water use systems

Dionysis ASSIMACOPOULOS[1], Athanasios ANGELIS-DIMAKIS[1] and George ARAMPATZIS[1]

[1] National Technical University of Athens, Greece

2.1.1 Abstract

Eco-efficiency has recently become an important concept of environmental decision making, serving as a policy objective and linked with resource efficiency it can be a measure of progress towards sustainability. The need for improving eco-efficiency leads to the challenge of identifying the most promising alternative solutions which improve both the economic and the environmental performance of a given system (“eco-innovations”). However, interventions in complex physical systems may lead to large-scale transformations and a systemic approach towards eco-innovation is required, in order to capture the complexity of all interrelated aspects and the interactions among the actors involved.

The goal of this paper is to present a methodology, developed in the context of the EcoWater research project, for the eco-efficiency assessment of a water use system at the meso level and the estimation of the anticipated eco-efficiency improvement from the introduction of innovative technologies, through a set of representative indicators.

A meso-level water use system combines a typical water supply chain with the corresponding production chain. It incorporates both the physical structure of the system and the rules governing the operation, performance and interactions of the system components. In such a system, water is considered in three different ways: (i) as a resource, (ii) as a productive input, and (iii) as a waste stream.

The developed methodological framework consists of four distinct steps. The first step leads to a clear, transparent mapping of the system at hand and the respective value chain, while the second step provides the means to assess its eco-efficiency. The assessment of the environmental performance follows a life-cycle oriented approach using the midpoint impact categories (including the impacts from the background systems). The economic performance of the water use system is measured using the Total Value Added to the product due to water use. One important novelty is the distribution of economic costs/benefits and environmental pressures over different stages and stakeholders in the value chain. The third step includes the selection of innovative technologies, which are assessed in the last step and combined with mid-term scenarios to determine the feasibility of their implementation.

Such as a systemic approach provides a concrete, comprehensive and accurate assessment of the economic and environmental performance of the system but also entails the consideration of the interdependencies and the economic interactions of all the heterogeneous actors involved in these two chains. Furthermore, the meso-level can act as an intermediate step in technological transition; between the technological niches (in the micro-level) and the wide adoption (or rejection) of new technologies (in the macro-level). In the meso level, all involved actors are urged to cooperate in order to (a) propose and build innovative technological solutions that will improve the overall eco-efficiency of the system; and (b) provide the necessary policy framework that will facilitate and promote their uptake. This ensures that upstream decisions in the value chain are coordinated with downstream activities and all potential synergies are identified, leading to the creation of "meso-level closed resource loops" and thus the promotion of a circular economy.

Keywords
Systemic eco-efficiency, water use systems, value chain, eco-innovation

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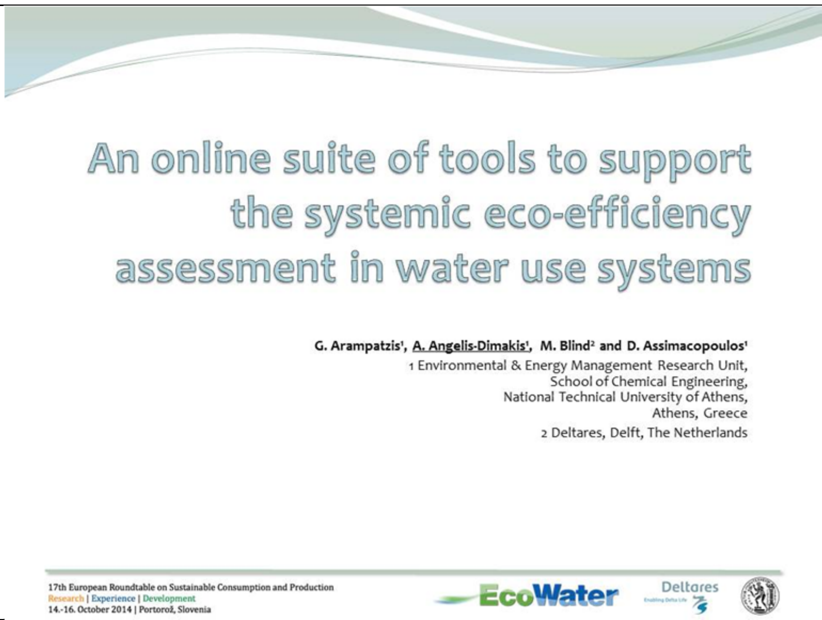
2.1.2 Presentation

(1)	

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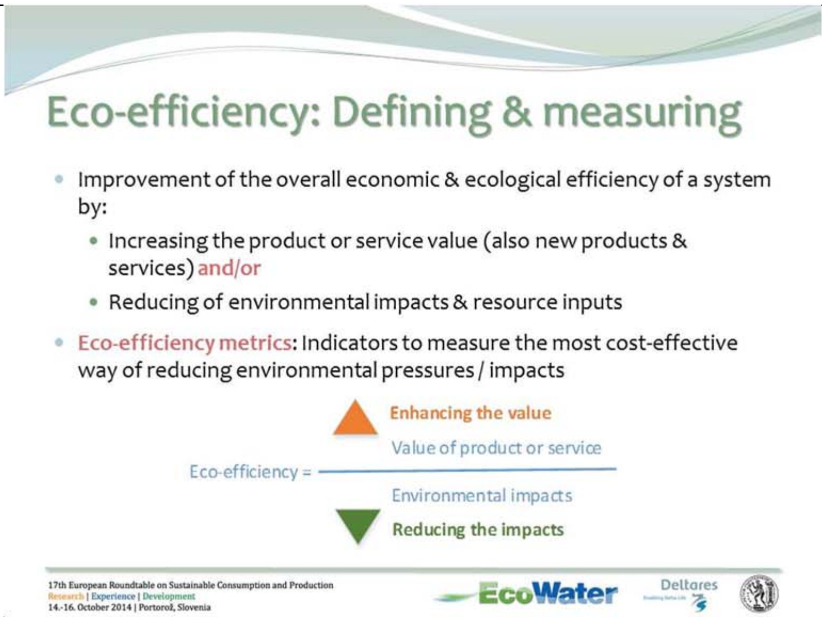
Eco-efficiency: Defining & measuring
Improvement of the overall economic & ecological efficiency of a system by:
Increasing the product or service value (also new products & services) and/or
Reducing of environmental impacts & resource inputs
Eco-efficiency metrics: Indicators to measure the most cost-effective way of reducing environmental pressures / impacts
Enhancing the value
Value of product or service
Eco-efficiency =
Environmental impacts
Reducing the impacts
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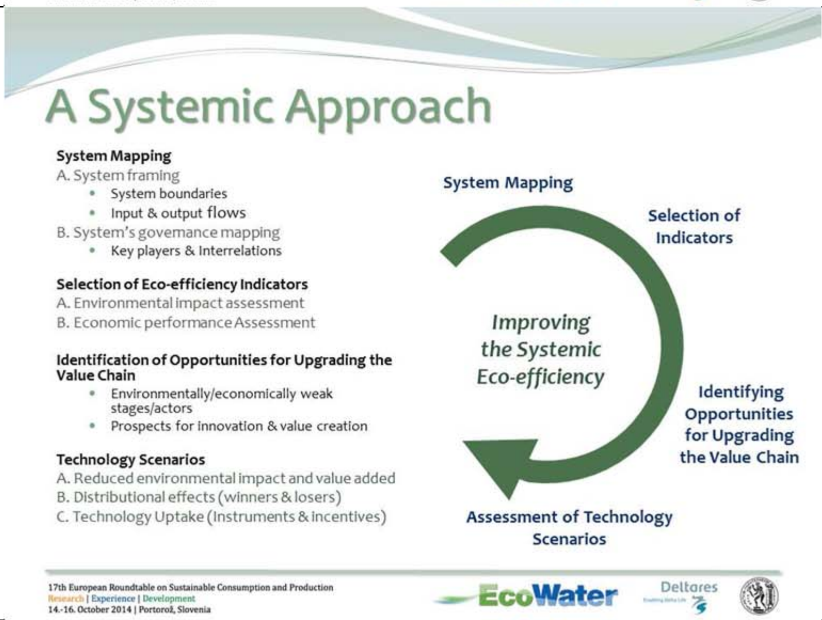
A Systemic Approach
System Mapping
A. System framing
System boundaries
Input & output flows
B. System's governance mapping
Key players & Interrelations
Selection of Eco-efficiency Indicators
A. Environmental impact assessment
B. Economic performance Assessment
Identification of Opportunities for Upgrading the Value Chain
Environmentally/economically weak stages/actors
Prospects for innovation & value creation
Technology Scenarios
A. Reduced environmental impact and value added
B. Distributional effects (winners & losers)
C. Technology Uptake (Instruments & incentives)
System Mapping
Selection of Indicators
Improving the Systemic Eco-efficiency
Identifying Opportunities for Upgrading the Value Chain
Assessment of Technology Scenarios
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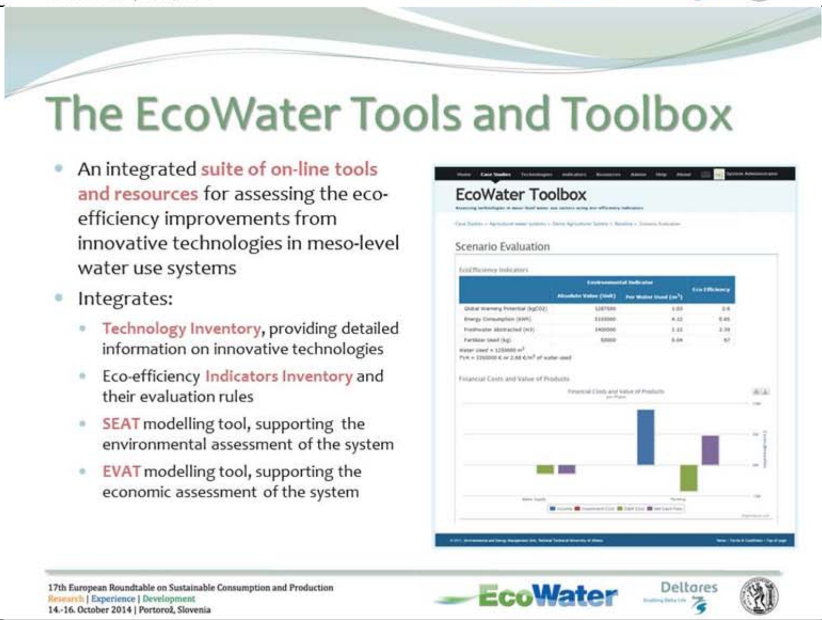
The EcoWater Tools and Toolbox
An integrated suite of on-line tools and resources for assessing the eco-efficiency improvements from innovative technologies in meso-level water use systems
Integrates:
Technology Inventory, providing detailed information on innovative technologies
Eco-efficiency Indicators Inventory and their evaluation rules
SEAT modelling tool, supporting the environmental assessment of the system
EVAT modelling tool, supporting the economic assessment of the system
EcoWater Toolbox
Scenario Evaluation
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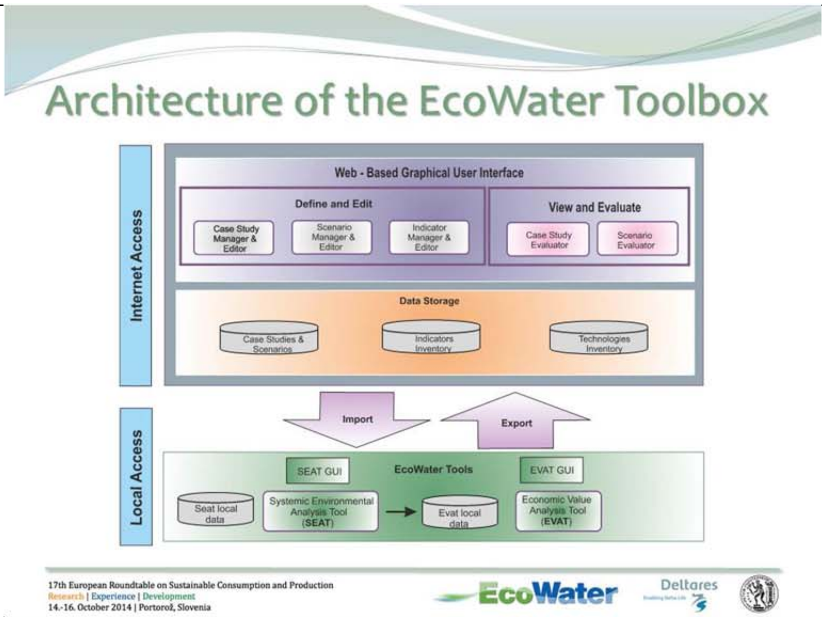
Architecture of the EcoWater Toolbox
Internet Access
Web - Based Graphical User Interface
Define and Edit
Case Study Manager & Editor
Scenario Manager & Editor
Indicator Manager & Editor
View and Evaluate
Case Study Evaluator
Scenario Evaluator
Data Storage
Case Studies & Scenarios
Indicators Inventory
Technologies Inventory
Import
Export
Local Access
SEAT GUI
EcoWater Tools
EVAT GUI
Seat local data
Systemic Environmental Analysis Tool (SEAT)
Evat local data
Economic Value Analysis Tool (EVAT)
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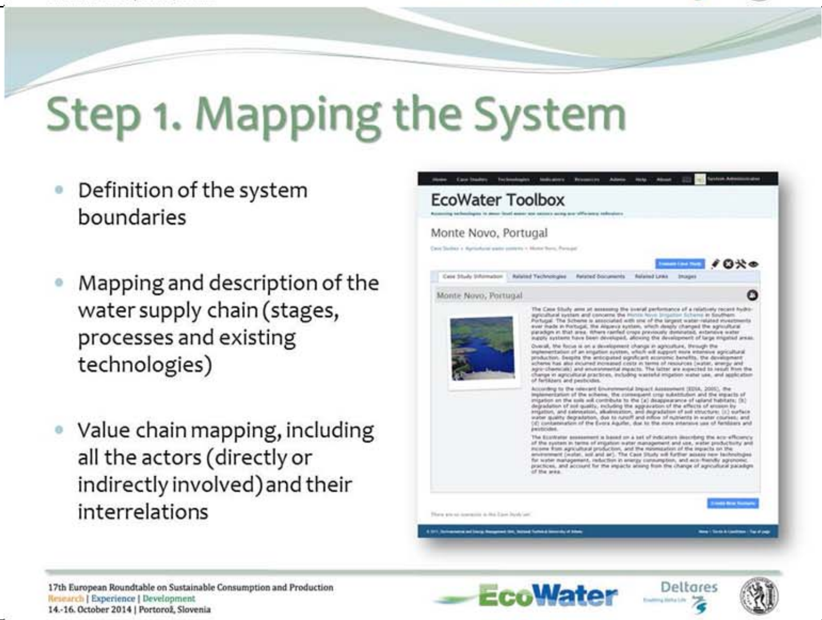
Step 1. Mapping the System
Definition of the system boundaries
Mapping and description of the water supply chain (stages, processes and existing technologies)
Value chain mapping, including all the actors (directly or indirectly involved) and their interrelations
EcoWater Toolbox
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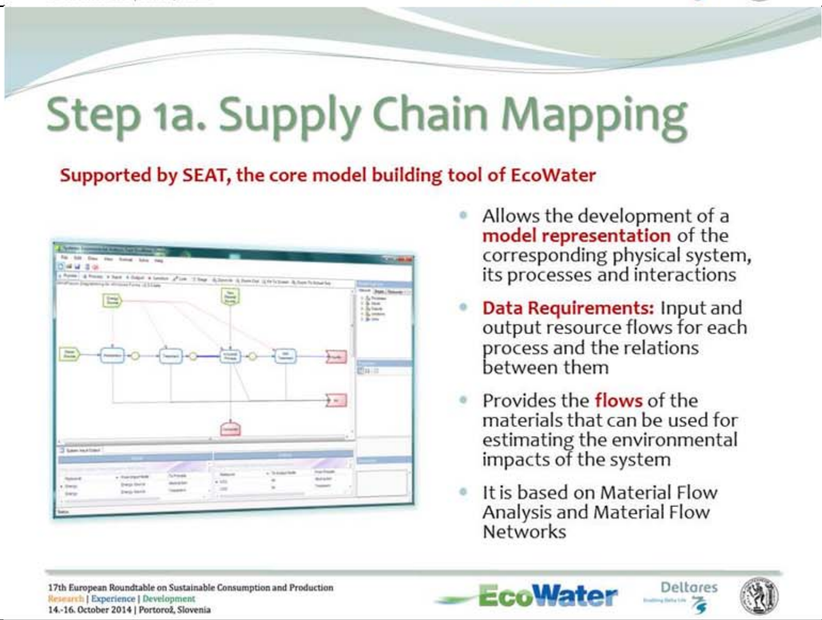
Step 1a. Supply Chain Mapping
Supported by SEAT, the core model building tool of EcoWater
Allows the development of a model representation of the corresponding physical system, its processes and interactions
Data Requirements: Input and output resource flows for each process and the relations between them
Provides the flows of the materials that can be used for estimating the environmental impacts of the system
It is based on Material Flow Analysis and Material Flow Networks
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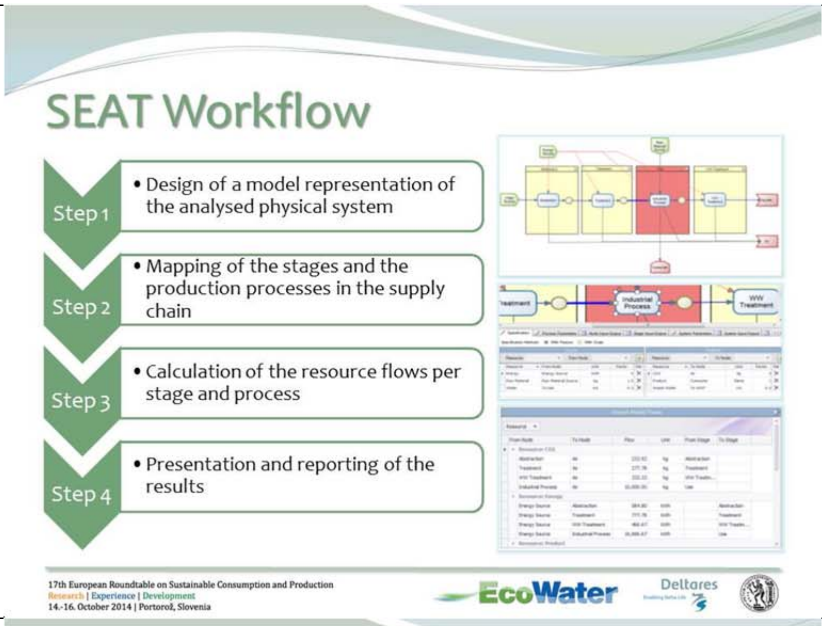
SEAT Workflow
Step 1
• Design of a model representation of the analysed physical system
Step 2
• Mapping of the stages and the production processes in the supply chain
Step 3
• Calculation of the resource flows per stage and process
Step 4
• Presentation and reporting of the results
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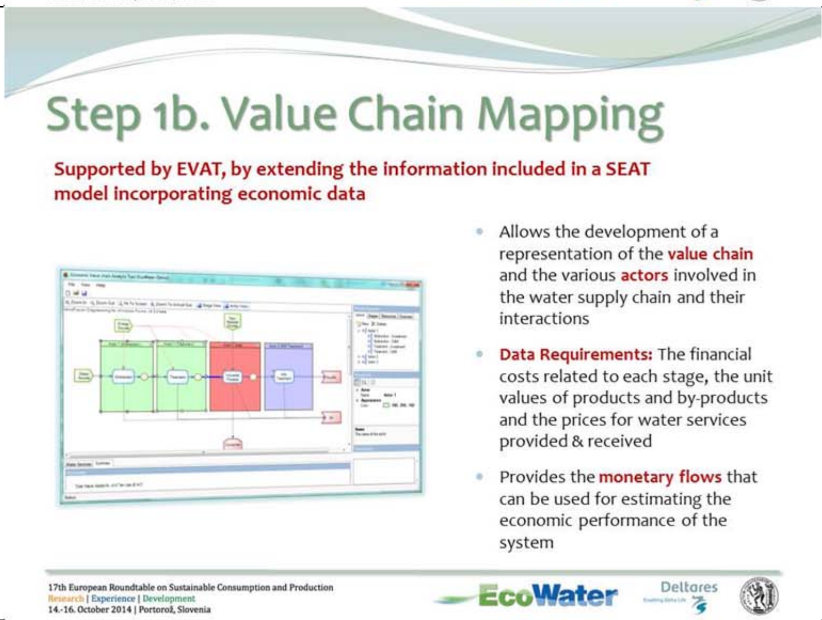
Step 1b. Value Chain Mapping
Supported by EVAT, by extending the information included in a SEAT model incorporating economic data
• Allows the development of a representation of the value chain and the various actors involved in the water supply chain and their interactions
• Data Requirements: The financial costs related to each stage, the unit values of products and by-products and the prices for water services provided & received
• Provides the monetary flows that can be used for estimating the economic performance of the system
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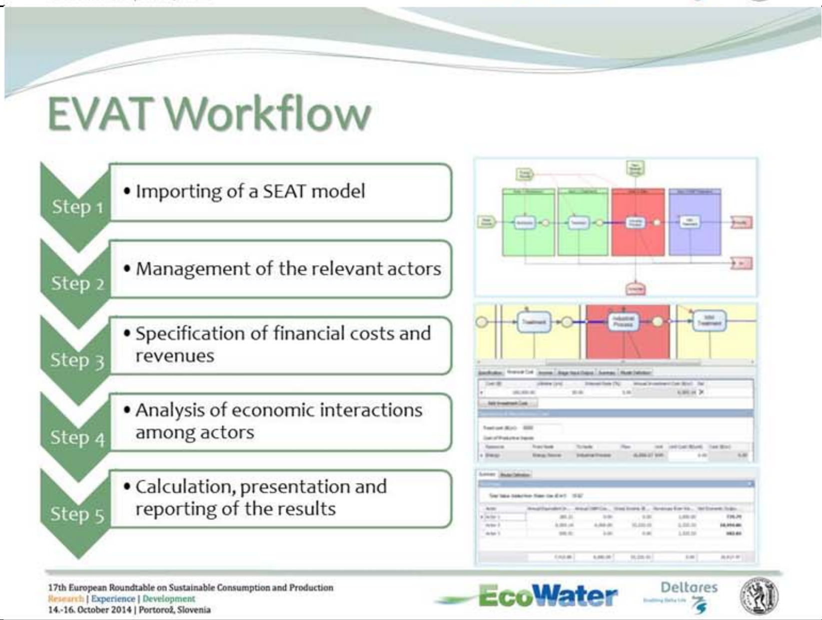
EVAT Workflow
Step 1
• Importing of a SEAT model
Step 2
• Management of the relevant actors
Step 3
• Specification of financial costs and revenues
Step 4
• Analysis of economic interactions among actors
Step 5
• Calculation, presentation and reporting of the results
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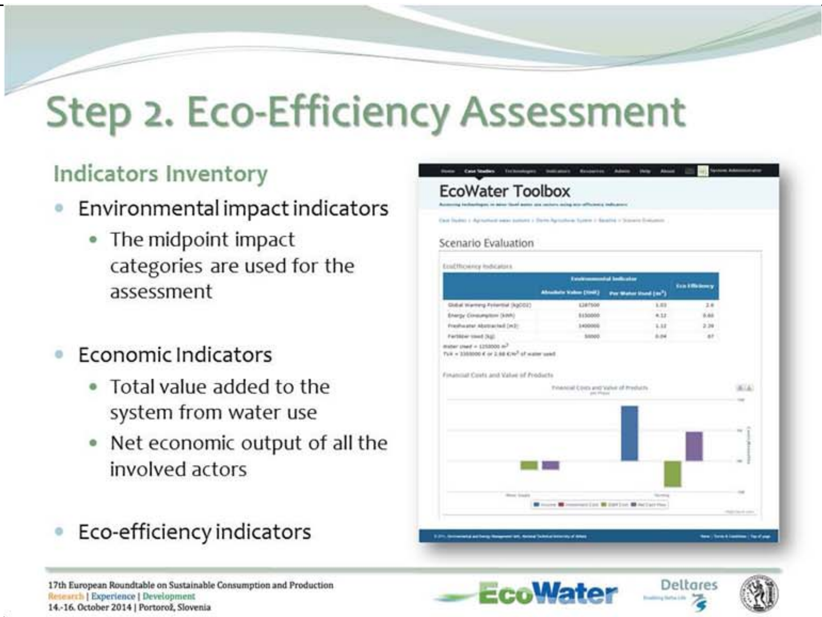

Step 2. Eco-Efficiency Assessment
Indicators Inventory
Environmental impact indicators
The midpoint impact categories are used for the assessment
Economic Indicators
Total value added to the system from water use
Net economic output of all the involved actors
Eco-efficiency indicators
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Scenario Evaluation
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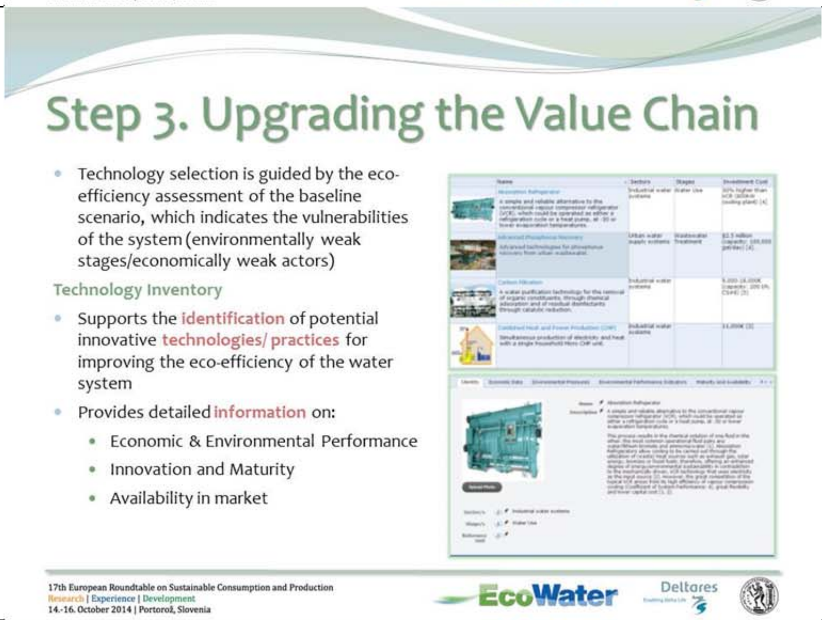

Step 3. Upgrading the Value Chain
Technology selection is guided by the eco-efficiency assessment of the baseline scenario, which indicates the vulnerabilities of the system (environmentally weak stages/economically weak actors)
Technology Inventory
Supports the identification of potential innovative technologies/ practices for improving the eco-efficiency of the water system
Provides detailed information on:
Economic & Environmental Performance
Innovation and Maturity
Availability in market
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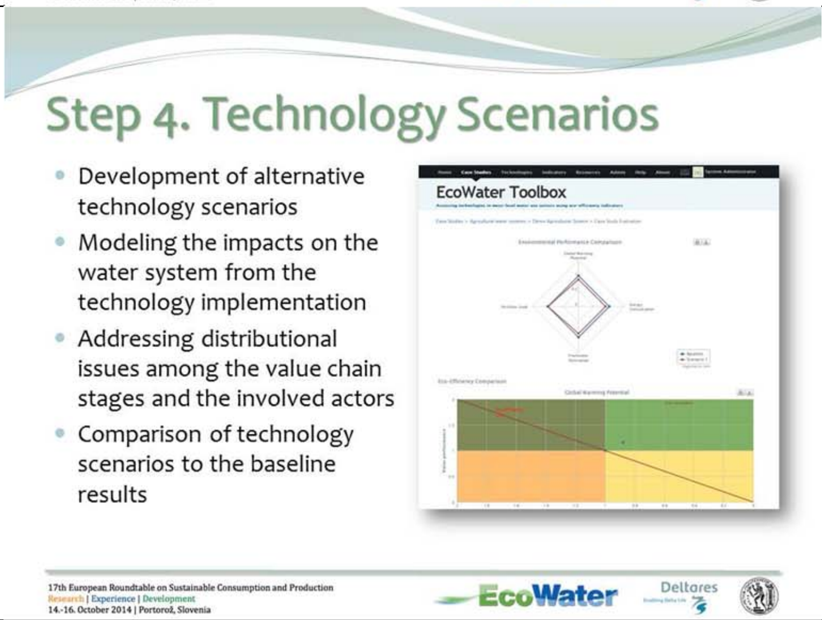

Step 4. Technology Scenarios
Development of alternative technology scenarios
Modeling the impacts on the water system from the technology implementation
Addressing distributional issues among the value chain stages and the involved actors
Comparison of technology scenarios to the baseline results
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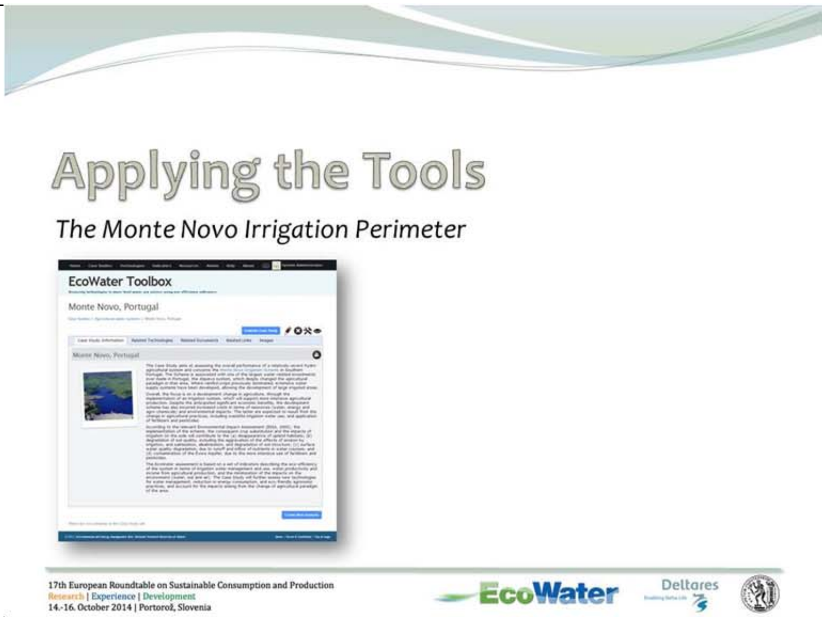
<tr><td>(14)</td><td>
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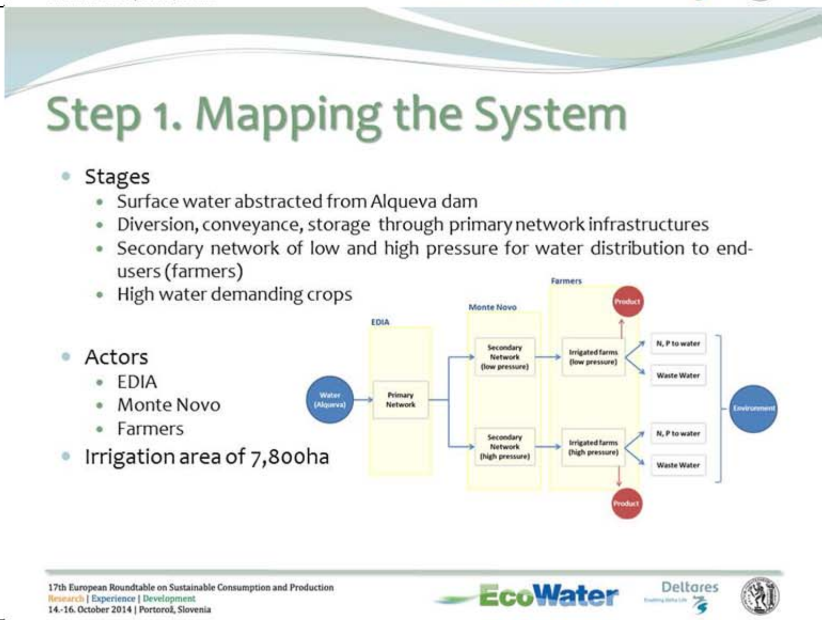
<tr><td>(15)</td><td>
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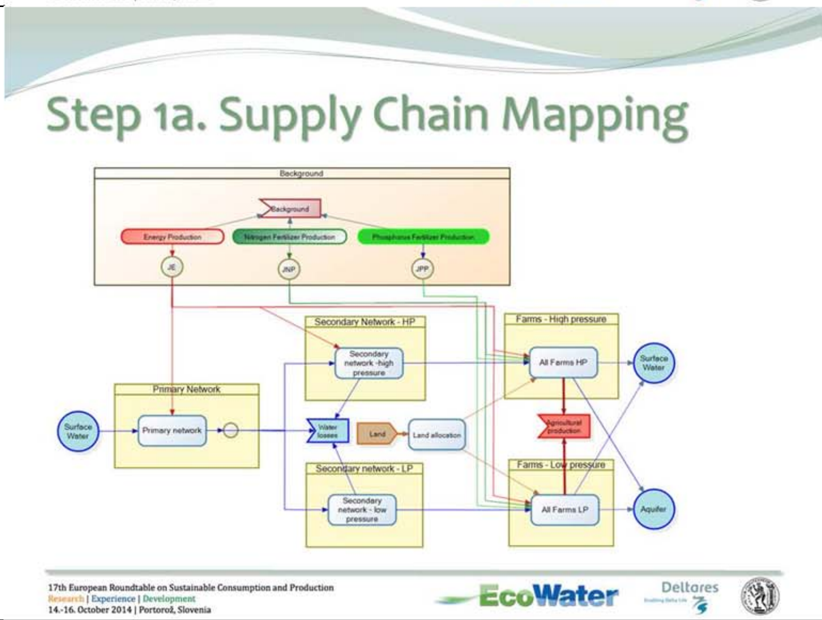
<tr><td>(16)</td><td>
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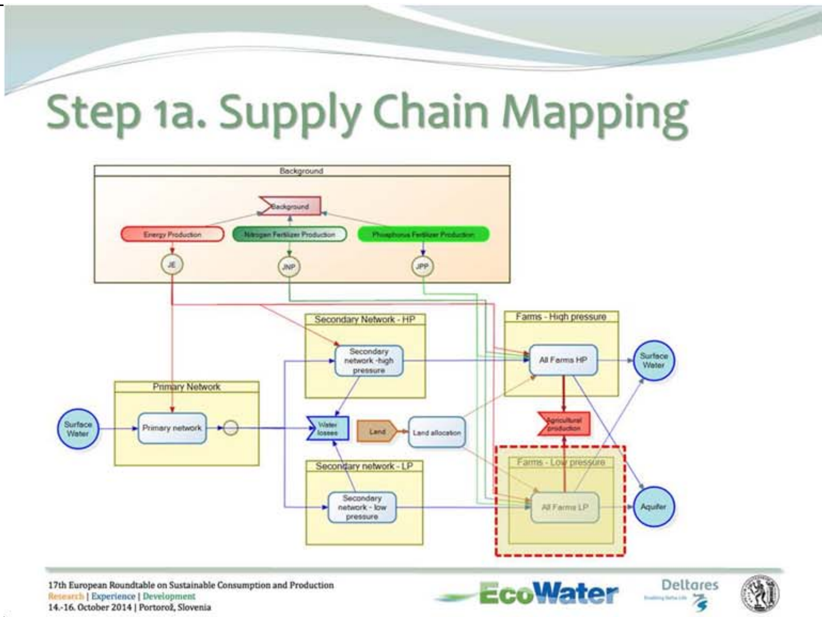
Step 1a. Supply Chain Mapping
Background
Background
Energy Production
Nitrogen Fertilizer Production
Phosphorus Fertilizer Production
JE
JNP
JPP
Secondary Network - HP
Secondary network -high pressure
Farms - High pressure
All Farms HP
Surface Water
Primary Network
Surface Water
Primary network
Water losses
Land
Land allocation
Agricultural production
Secondary network - LP
Secondary network - low pressure
Farms - Low pressure
All Farms LP
Aquifer
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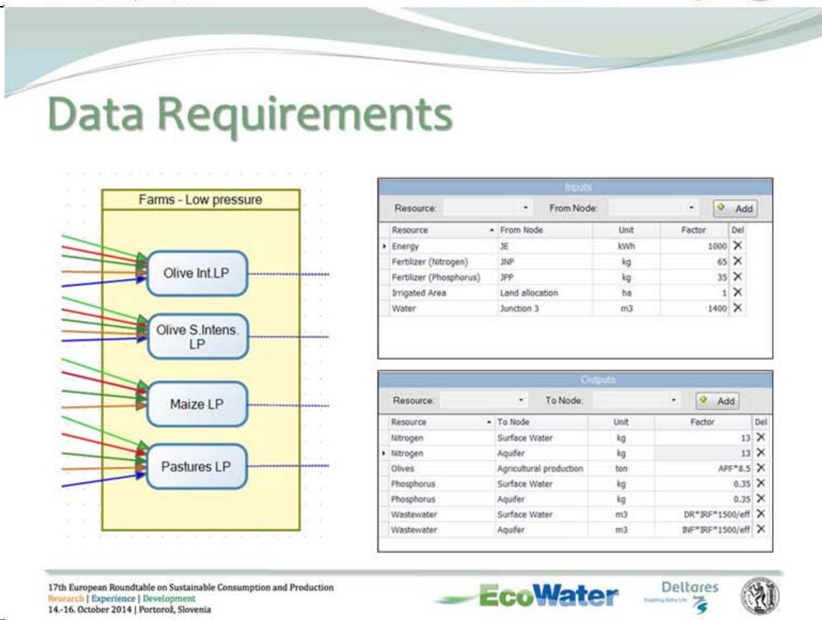
Data Requirements
Farms - Low pressure
Olive Int.LP
Olive S.Intens. LP
Maize LP
Pastures LP
Inputs
Resource: From Node: Add
Resource | From Node | Unit | Factor | Del
Energy | JE | kWh | 1000
Fertilizer (Nitrogen) | JNP | kg | 65
Fertilizer (Phosphorus) | JPP | kg | 35
Irrigated Area | Land allocation | ha | 1
Water | Junction 3 | m3 | 1400
Outputs
Resource: To Node: Add
Resource | To Node | Unit | Factor | Del
Nitrogen | Surface Water | kg | 13
Nitrogen | Aquifer | kg | 13
Olives | Agricultural production | ton | APF*8.5
Phosphorus | Surface Water | kg | 0.35
Phosphorus | Aquifer | kg | 0.35
Wastewater | Surface Water | m3 | DR*IRF*1500/eff
Wastewater | Aquifer | m3 | INF*IRF*1500/eff
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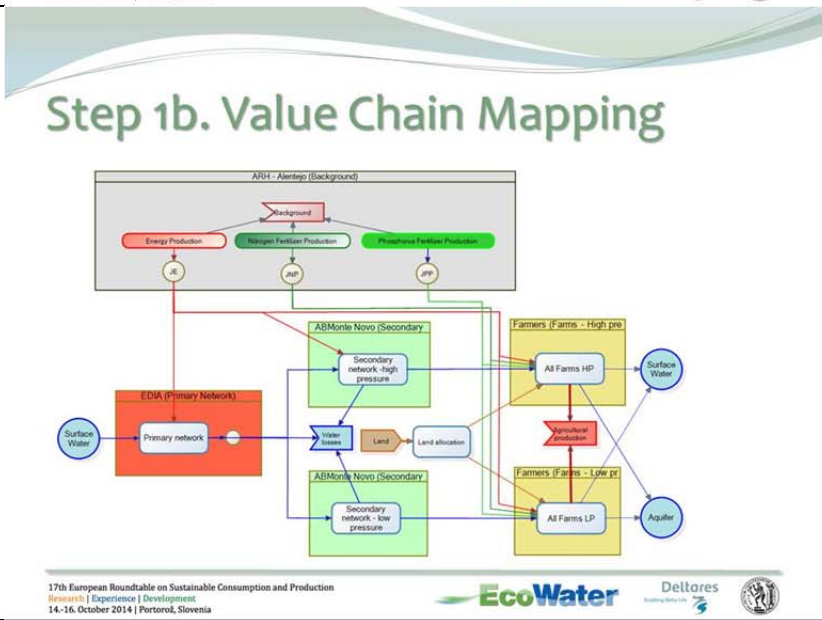
Step 1b. Value Chain Mapping
ARH - Alentejo (Background)
Background
Energy Production
Nitrogen Fertilizer Production
Phosphorus Fertilizer Production
JE
JNP
JPP
ABMonte Novo (Secondary
Secondary network -high pressure
Farmers (Farms - High pre
All Farms HP
Surface Water
EDIA (Primary Network)
Surface Water
Primary network
Water losses
Land
Land allocation
Agricultural production
ABMonte Novo (Secondary
Secondary network - low pressure
Farmers (Farms - Low pr
All Farms LP
Aquifer
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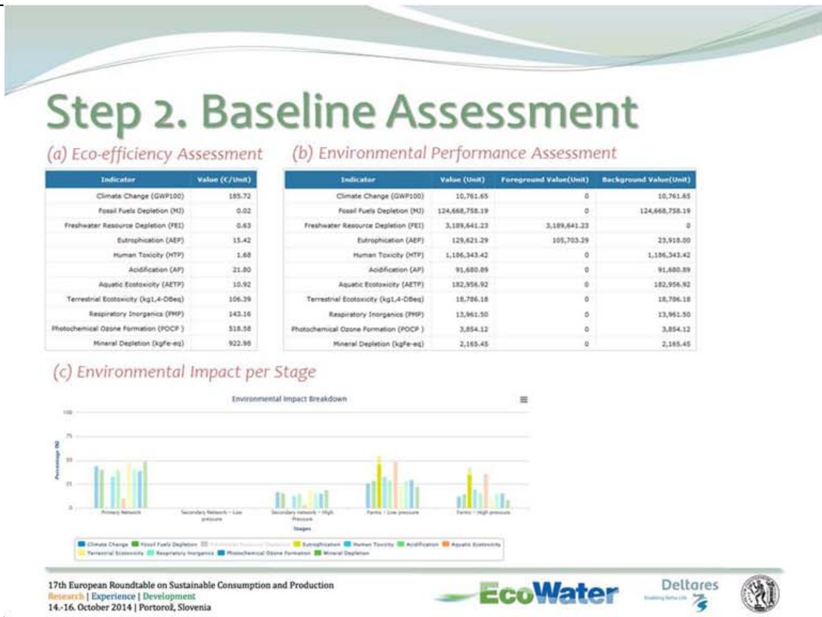
Step 2. Baseline Assessment
(a) Eco-efficiency Assessment
Indicator | Value (€/Unit)
Climate Change (GWP100) | 185.72
Fossil Fuels Depletion (MJ) | 0.02
Freshwater Resource Depletion (FEI) | 0.63
Eutrophication (AEP) | 15.42
Human Toxicity (HTP) | 1.68
Acidification (AP) | 21.80
Aquatic Ecotoxicity (AETP) | 10.92
Terrestrial Ecotoxicity (kg1,4-DBeq) | 106.39
Respiratory Inorganics (PMP) | 143.16
Photochemical Ozone Formation (POCP) | 518.58
Mineral Depletion (kgfe-eq) | 922.98
(b) Environmental Performance Assessment
Indicator | Value (Unit) | Foreground Value(Unit) | Background Value(Unit)
Climate Change (GWP100) | 10,761.65 | 0 | 10,761.65
Fossil Fuels Depletion (MJ) | 124,668,758.19 | 0 | 124,668,758.19
Freshwater Resource Depletion (FEI) | 3,189,641.23 | 3,189,641.23 | 0
Eutrophication (AEP) | 129,621.29 | 105,703.29 | 23,918.00
Human Toxicity (HTP) | 1,186,343.42 | 0 | 1,186,343.42
Acidification (AP) | 91,680.89 | 0 | 91,680.89
Aquatic Ecotoxicity (AETP) | 182,956.92 | 0 | 182,956.92
Terrestrial Ecotoxicity (kg1,4-DBeq) | 18,786.18 | 0 | 18,786.18
Respiratory Inorganics (PMP) | 13,961.50 | 0 | 13,961.50
Photochemical Ozone Formation (POCP) | 3,854.12 | 0 | 3,854.12
Mineral Depletion (kgfe-eq) | 2,165.45 | 0 | 2,165.45
(c) Environmental Impact per Stage
Environmental Impact Breakdown
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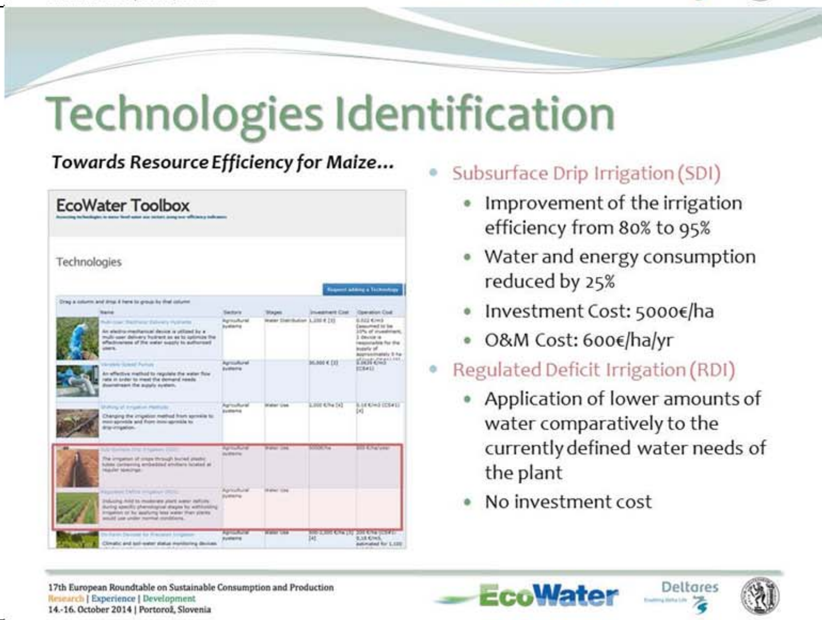
Technologies Identification
Towards Resource Efficiency for Maize…
EcoWater Toolbox
Technologies
Subsurface Drip Irrigation (SDI)
Improvement of the irrigation efficiency from 80% to 95%
Water and energy consumption reduced by 25%
Investment Cost: 5000€/ha
O&M Cost: 600€/ha/yr
Regulated Deficit Irrigation (RDI)
Application of lower amounts of water comparatively to the currently defined water needs of the plant
No investment cost
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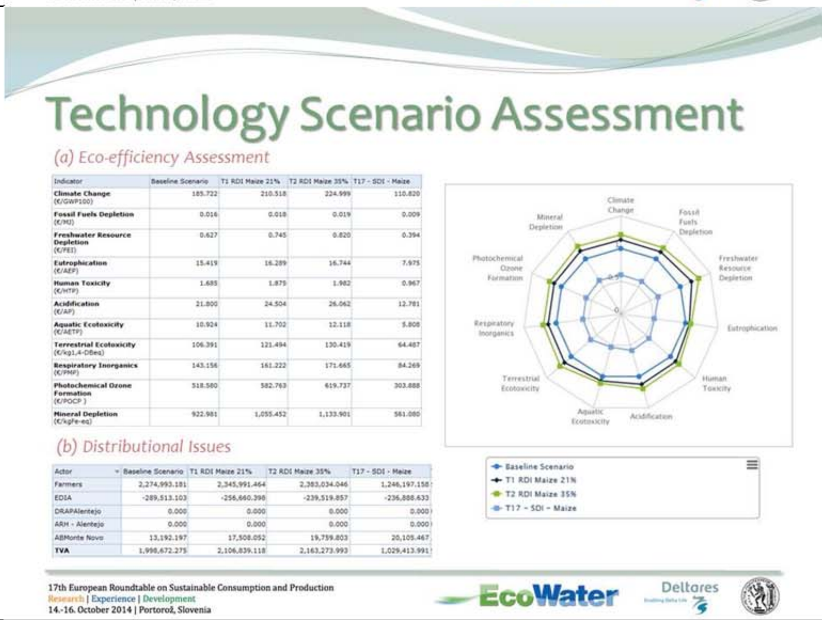
Technology Scenario Assessment
(a) Eco-efficiency Assessment
Indicator | Baseline Scenario | T1 RDI Maize 21% | T2 RDI Maize 35% | T17 - SDI - Maize
Climate Change (€/GWP100) | 185.722 | 210.518 | 224.999 | 110.820
Fossil Fuels Depletion (€/MJ) | 0.016 | 0.018 | 0.019 | 0.009
Freshwater Resource Depletion (€/FEI) | 0.627 | 0.745 | 0.820 | 0.394
Eutrophication (€/AEP) | 15.419 | 16.289 | 16.744 | 7.975
Human Toxicity (€/HTP) | 1.685 | 1.875 | 1.982 | 0.967
Acidification (€/AP) | 21.800 | 24.504 | 26.062 | 12.781
Aquatic Ecotoxicity (€/AETP) | 10.924 | 11.702 | 12.118 | 5.808
Terrestrial Ecotoxicity (€/kg1,4-DBeq) | 106.391 | 121.494 | 130.419 | 64.487
Respiratory Inorganics (€/PMP) | 143.156 | 161.222 | 171.665 | 84.269
Photochemical Ozone Formation (€/POCP) | 518.580 | 582.763 | 619.737 | 303.888
Mineral Depletion (€/kgFe-eq) | 922.981 | 1,055.452 | 1,133.901 | 581.080
(b) Distributional Issues
Actor | Baseline Scenario | T1 RDI Maize 21% | T2 RDI Maize 35% | T17 - SDI - Maize
Farmers | 2,274,993.181 | 2,345,991.464 | 2,383,034.046 | 1,246,197.158
EDIA | -289,513.103 | -256,660.398 | -239,519.857 | -236,888.633
DRAPAlentejo | 0.000 | 0.000 | 0.000 | 0.000
ARH - Alentejo | 0.000 | 0.000 | 0.000 | 0.000
ABMonte Novo | 13,192.197 | 17,508.052 | 19,759.803 | 20,105.467
TVA | 1,998,672.275 | 2,106,839.118 | 2,163,273.993 | 1,029,413.991
Climate Change
Fossil Fuels Depletion
Freshwater Resource Depletion
Eutrophication
Human Toxicity
Acidification
Aquatic Ecotoxicity
Terrestrial Ecotoxicity
Respiratory Inorganics
Photochemical Ozone Formation
Mineral Depletion
Baseline Scenario
T1 RDI Maize 21%
T2 RDI Maize 35%
T17 - SDI - Maize
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2.2 An online suite of tools to support the systemic eco-efficiency assessment in water use systems

George ARAMPATZIS[1], Athanasios ANGELIS-DIMAKIS[1], Dionysis ASSIMACOPOULOS[1] and Michiel BLIND[2]

[1] National Technical University of Athens, Greece
[2] Deltares, The Netherlands

2.2.1 Abstract

Achieving sustainable development of water use systems requires methods and tools to help quantify and compare their performance. In recent policy frameworks, such as the Europe 2020 strategy, resource efficiency and resource productivity have been widely promoted for transforming economy into a sustainable one. Eco-efficiency is a more general concept that has been elaborated as a key instrument for promoting fundamental changes in the way societies produce and consume resources.

The eco-efficiency assessment of a water use system, as well as the estimation of the anticipated eco-efficiency improvement as a result of innovative practices/technologies, is a conceptually and methodologically challenging issue. A systemic approach is required to capture the complexity of all interrelated aspects and the interactions among the heterogeneous actors involved in the system. This involves mapping the behaviour of the system into representative models, structuring the analysis in easy to understand procedures and developing versatile software tools for supporting the analysis. Typical software tools focus on environmental aspects of a production system and their capabilities for simultaneously analysing economic aspects are usually limited. In order to go one step further and include the meso-level effects of technology decisions, models and tools that combine both economic and environmental perspectives should be developed.

In the context of the EcoWater research project, an integrated suite of on-line tools and resources (EcoWater Toolbox) for assessing eco-efficiency improvements from innovative technologies in water use systems at the meso-level has been developed. Equipped with a continuously updated inventory of currently available technological innovations as well as a list of eco-efficiency indicators, the Toolbox supports a comprehensive four-step assessment:
1. Allows the users to frame the case study by defining system boundaries, describing the water supply chain and value chains and including all the actors.
2. Helps the users to establish a baseline eco-efficiency assessment, using the integrated modelling tools.
3. Supports the users in identifying both sector-specific and system-wide

technologies and practices to suit their situation, through the integrated technology inventory.

4. Enables the users to assess innovative technology solutions by developing predictive technology scenarios and comparing these with baseline results.

At the core of the Toolbox are two modelling tools, which combine both economic and environmental viewpoints into a single modelling framework. The first tool, named “Systemic Environmental Analysis Tool” (SEAT), assists in building a representation of the physical system, its processes and interactions. This model forms the basis for evaluating the environmental performance of the system. The second tool, named “Economic Value chain Analysis Tool” (EVAT), supplements the analysis of SEAT addressing the value chain and focusing on the economic component of the eco-efficiency.

The methodology adopted and the operational aspects of the EcoWater Toolbox are presented in the current paper and demonstrated through the assessment of the environmental impacts and the eco-efficiency performance associated with the water value chain in the case of a milk production unit of a dairy industry.

Keywords

Eco-efficiency, meso-level, value-chain, environmental modelling, innovative technologies

Corresponding Author

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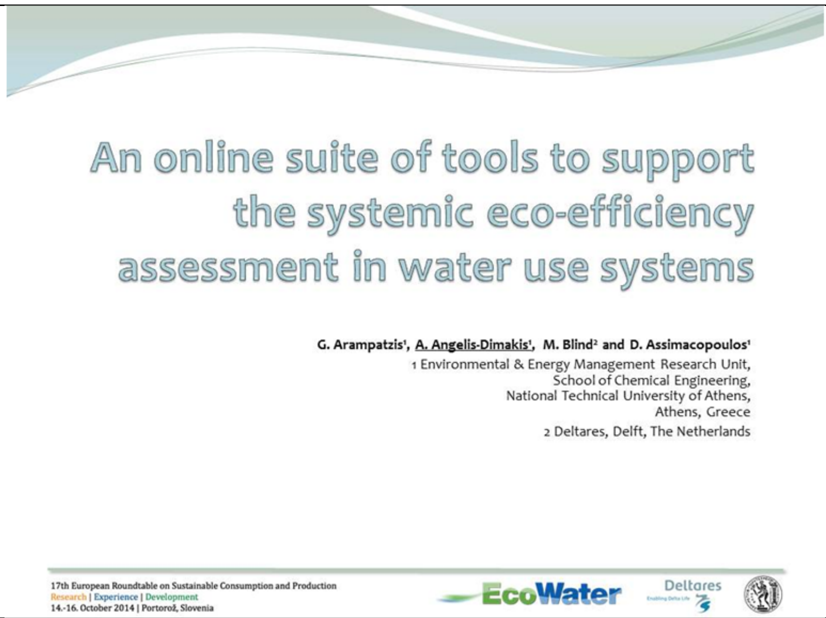
Mr. BLIND, Michiel; Deltares, The Netherlands

E-mail: assim@chemeng.ntua.gr

2.2.2 Presentation

(1)	

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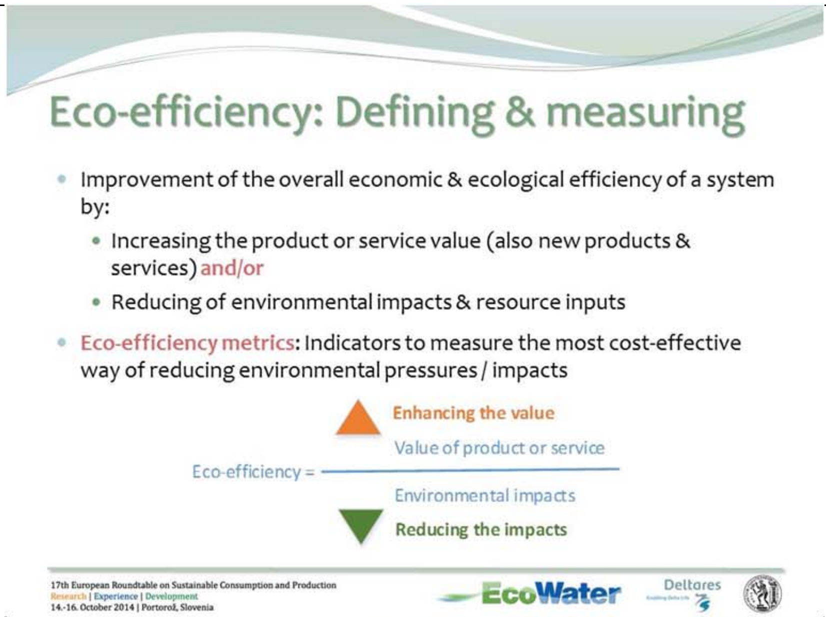
Eco-efficiency: Defining & measuring
Improvement of the overall economic & ecological efficiency of a system by:
Increasing the product or service value (also new products & services) and/or
Reducing of environmental impacts & resource inputs
Eco-efficiency metrics: Indicators to measure the most cost-effective way of reducing environmental pressures / impacts
Enhancing the value
Value of product or service
Eco-efficiency =
Environmental impacts
Reducing the impacts
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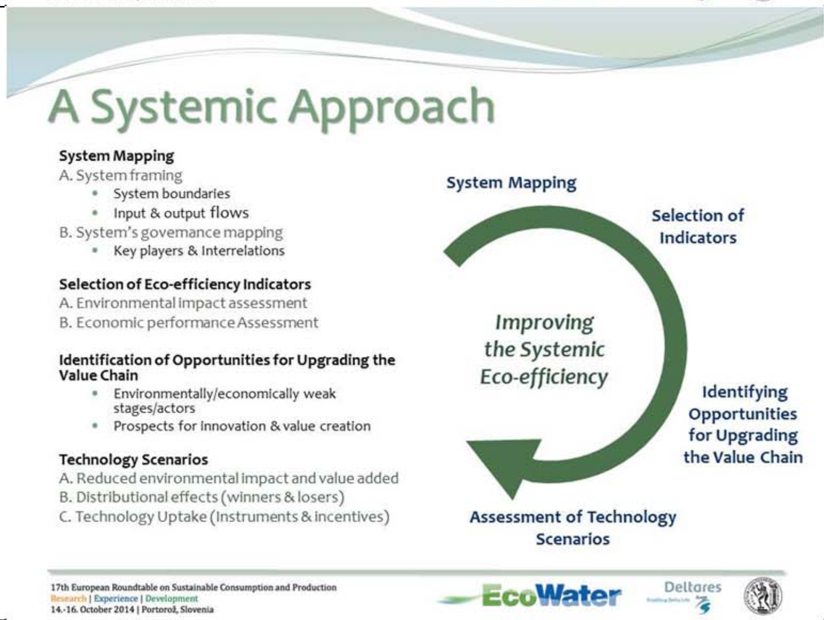
A Systemic Approach
System Mapping
A. System framing
System boundaries
Input & output flows
B. System's governance mapping
Key players & Interrelations
Selection of Eco-efficiency Indicators
A. Environmental impact assessment
B. Economic performance Assessment
Identification of Opportunities for Upgrading the Value Chain
Environmentally/economically weak stages/actors
Prospects for innovation & value creation
Technology Scenarios
A. Reduced environmental impact and value added
B. Distributional effects (winners & losers)
C. Technology Uptake (Instruments & incentives)
System Mapping
Selection of Indicators
Improving the Systemic Eco-efficiency
Identifying Opportunities for Upgrading the Value Chain
Assessment of Technology Scenarios
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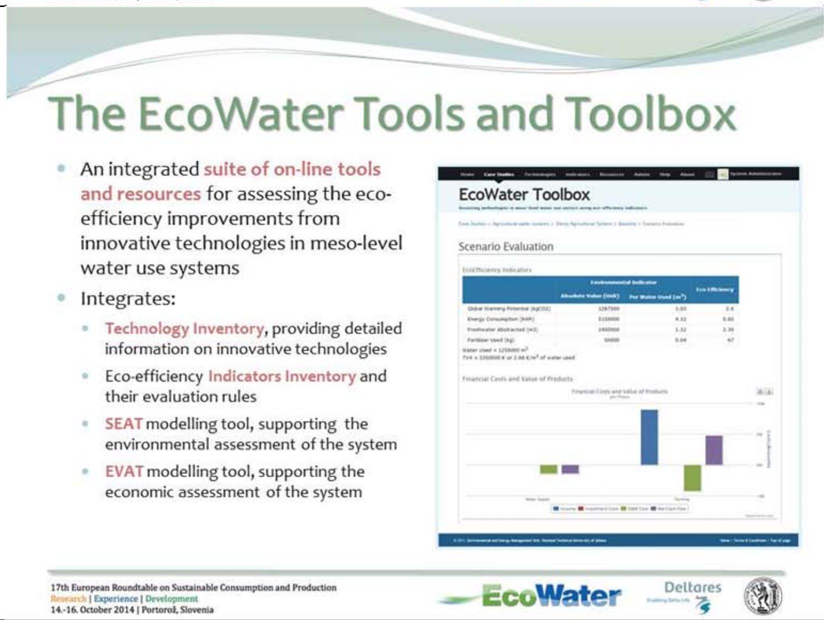
The EcoWater Tools and Toolbox
An integrated suite of on-line tools and resources for assessing the eco-efficiency improvements from innovative technologies in meso-level water use systems
Integrates:
Technology Inventory, providing detailed information on innovative technologies
Eco-efficiency Indicators Inventory and their evaluation rules
SEAT modelling tool, supporting the environmental assessment of the system
EVAT modelling tool, supporting the economic assessment of the system
EcoWater Toolbox
Scenario Evaluation
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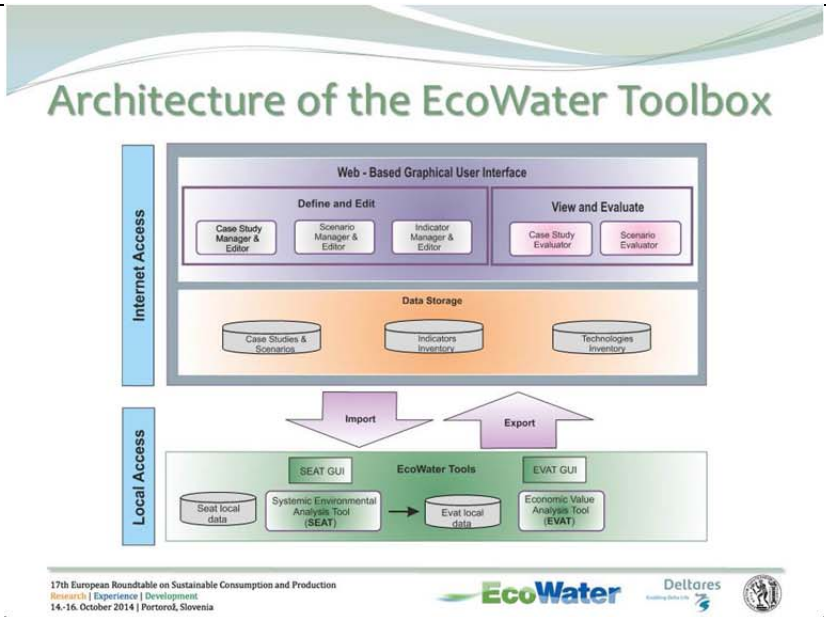
Architecture of the EcoWater Toolbox
Internet Access
Web - Based Graphical User Interface
Define and Edit
Case Study Manager & Editor
Scenario Manager & Editor
Indicator Manager & Editor
View and Evaluate
Case Study Evaluator
Scenario Evaluator
Data Storage
Case Studies & Scenarios
Indicators Inventory
Technologies Inventory
Import
Export
Local Access
SEAT GUI
EcoWater Tools
EVAT GUI
Seat local data
Systemic Environmental Analysis Tool (SEAT)
Evat local data
Economic Value Analysis Tool (EVAT)
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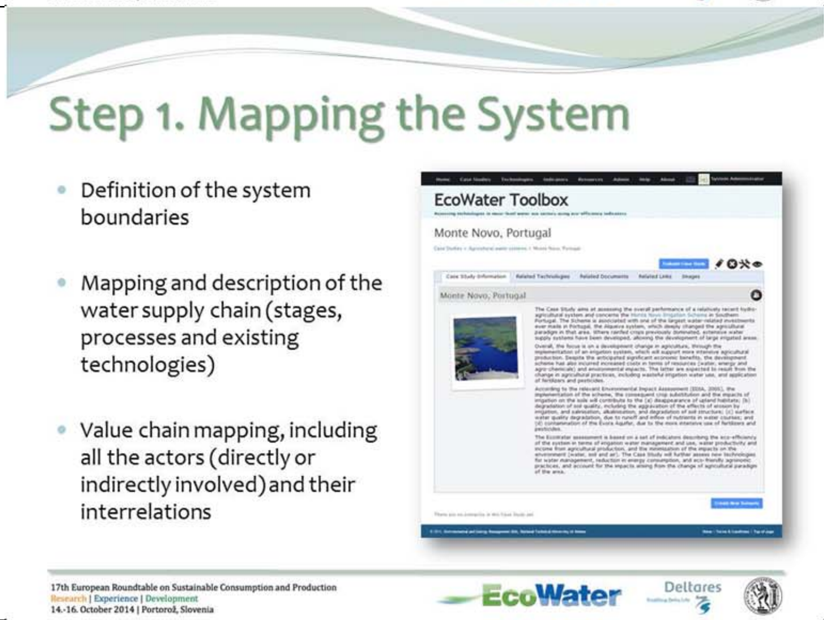
Step 1. Mapping the System
Definition of the system boundaries
Mapping and description of the water supply chain (stages, processes and existing technologies)
Value chain mapping, including all the actors (directly or indirectly involved) and their interrelations
EcoWater Toolbox
Monte Novo, Portugal
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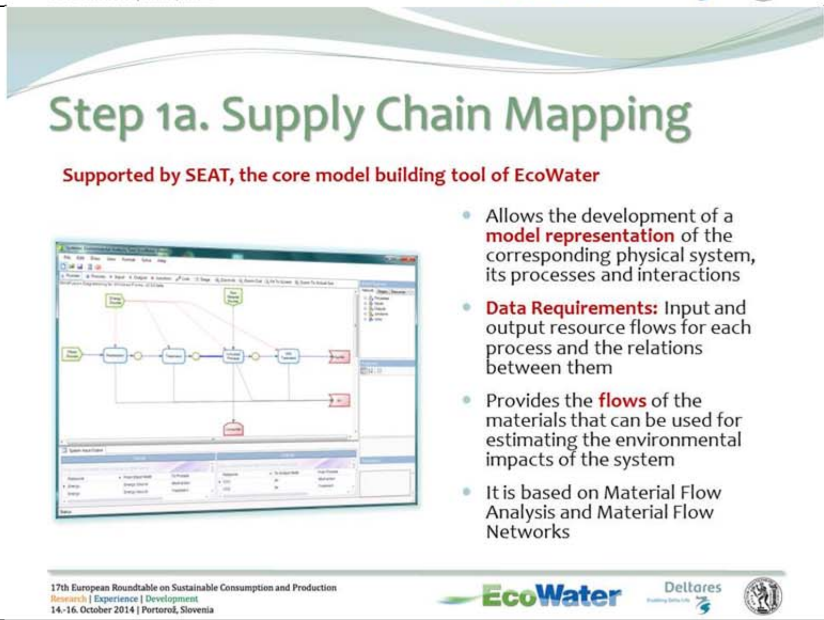
Step 1a. Supply Chain Mapping
Supported by SEAT, the core model building tool of EcoWater
Allows the development of a model representation of the corresponding physical system, its processes and interactions
Data Requirements: Input and output resource flows for each process and the relations between them
Provides the flows of the materials that can be used for estimating the environmental impacts of the system
It is based on Material Flow Analysis and Material Flow Networks
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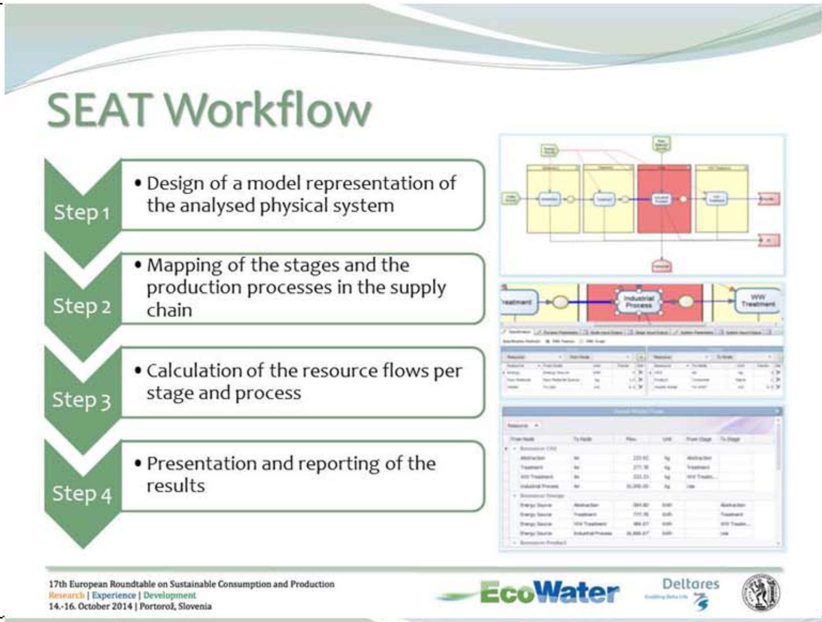

SEAT Workflow
Step 1
• Design of a model representation of the analysed physical system
Step 2
• Mapping of the stages and the production processes in the supply chain
Step 3
• Calculation of the resource flows per stage and process
Step 4
• Presentation and reporting of the results
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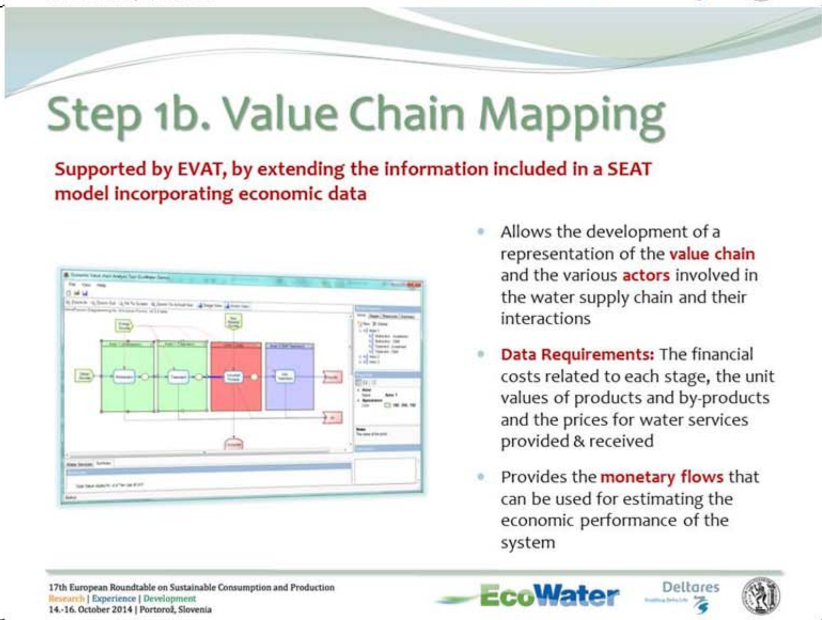

Step 1b. Value Chain Mapping
Supported by EVAT, by extending the information included in a SEAT model incorporating economic data
• Allows the development of a representation of the value chain and the various actors involved in the water supply chain and their interactions
• Data Requirements: The financial costs related to each stage, the unit values of products and by-products and the prices for water services provided & received
• Provides the monetary flows that can be used for estimating the economic performance of the system
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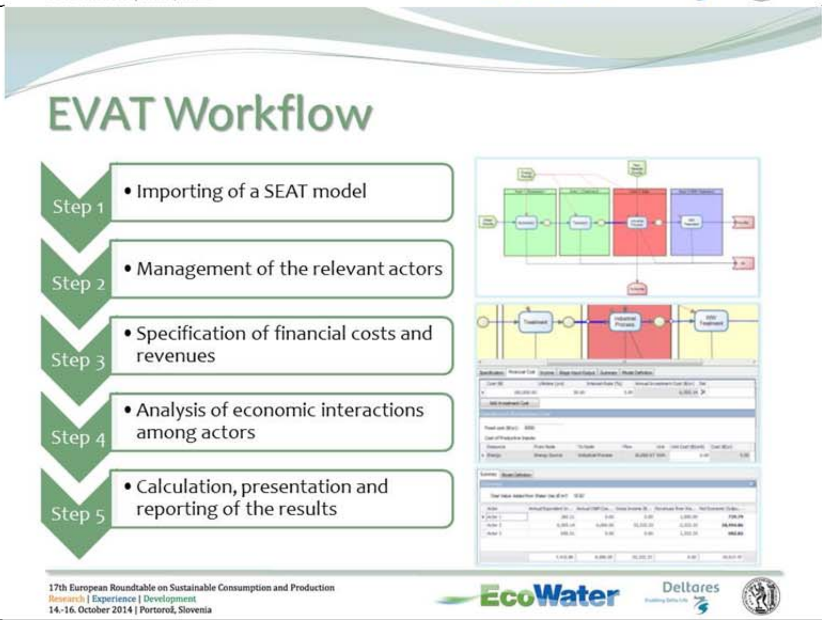

EVAT Workflow
Step 1
• Importing of a SEAT model
Step 2
• Management of the relevant actors
Step 3
• Specification of financial costs and revenues
Step 4
• Analysis of economic interactions among actors
Step 5
• Calculation, presentation and reporting of the results
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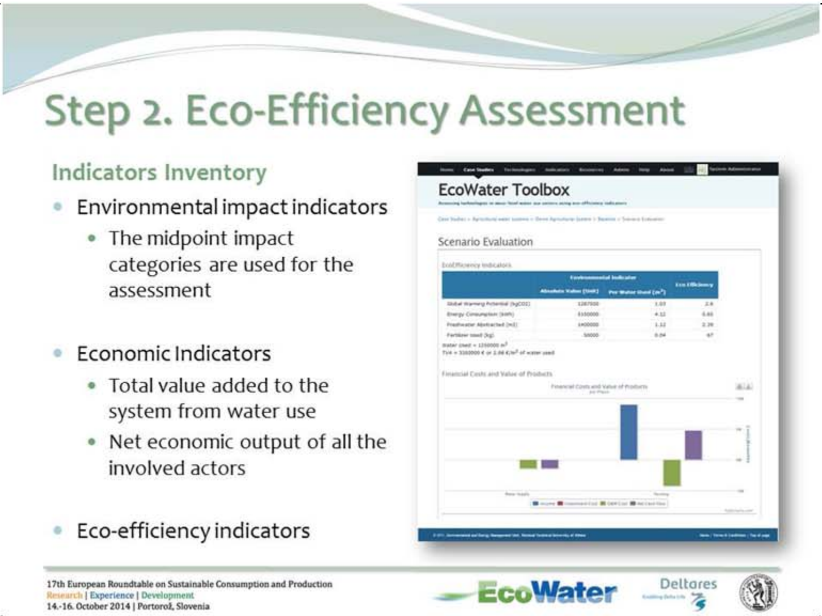
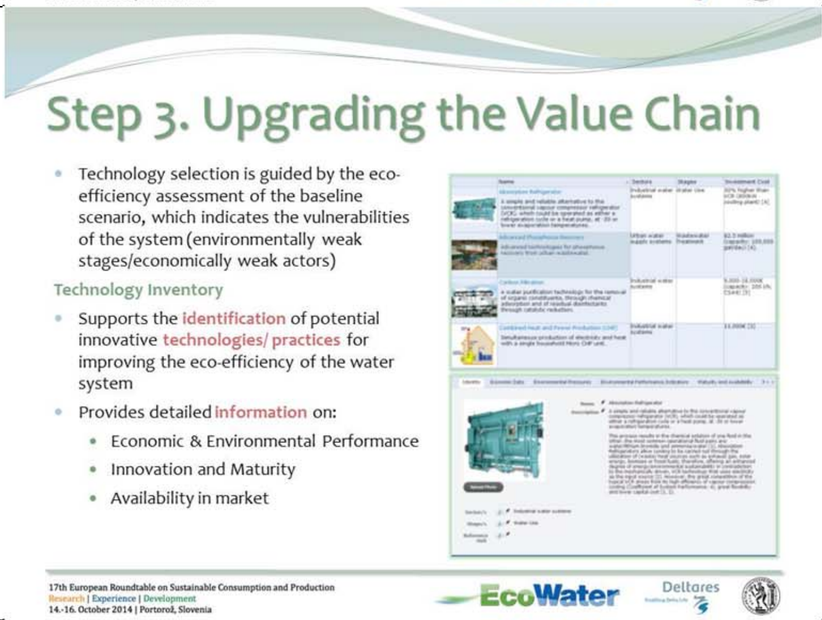
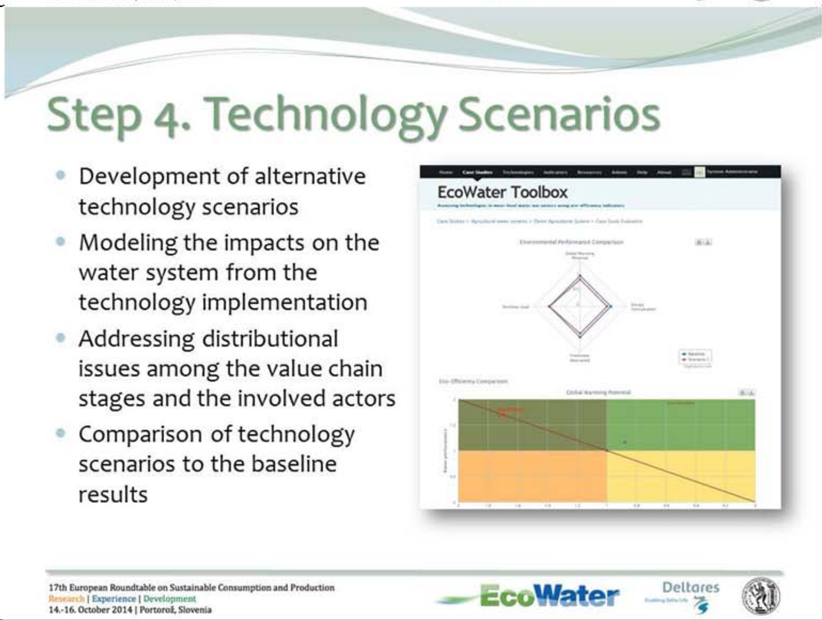
(11)	Step 2. Eco-Efficiency Assessment Indicators Inventory Environmental impact indicators The midpoint impact categories are used for the assessment Economic Indicators Total value added to the system from water use Net economic output of all the involved actors Eco-efficiency indicators EcoWater Toolbox Scenario Evaluation 17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater Deltares
(12)	Step 3. Upgrading the Value Chain Technology selection is guided by the eco-efficiency assessment of the baseline scenario, which indicates the vulnerabilities of the system (environmentally weak stages/economically weak actors) Technology Inventory Supports the identification of potential innovative technologies/ practices for improving the eco-efficiency of the water system Provides detailed information on: Economic & Environmental Performance Innovation and Maturity Availability in market 17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater Deltares
(13)	Step 4. Technology Scenarios Development of alternative technology scenarios Modeling the impacts on the water system from the technology implementation Addressing distributional issues among the value chain stages and the involved actors Comparison of technology scenarios to the baseline results EcoWater Toolbox 17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater Deltares

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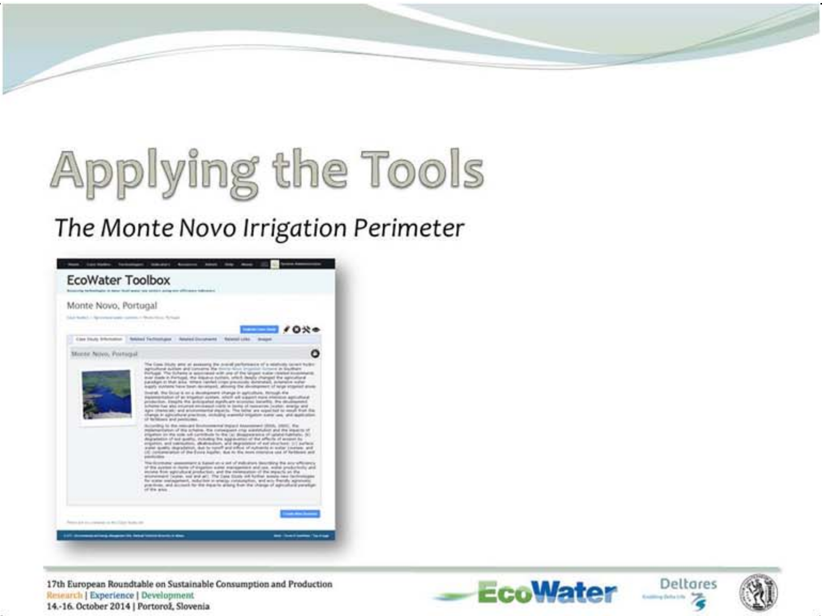

Applying the Tools
The Monte Novo Irrigation Perimeter
EcoWater Toolbox
Monte Novo, Portugal
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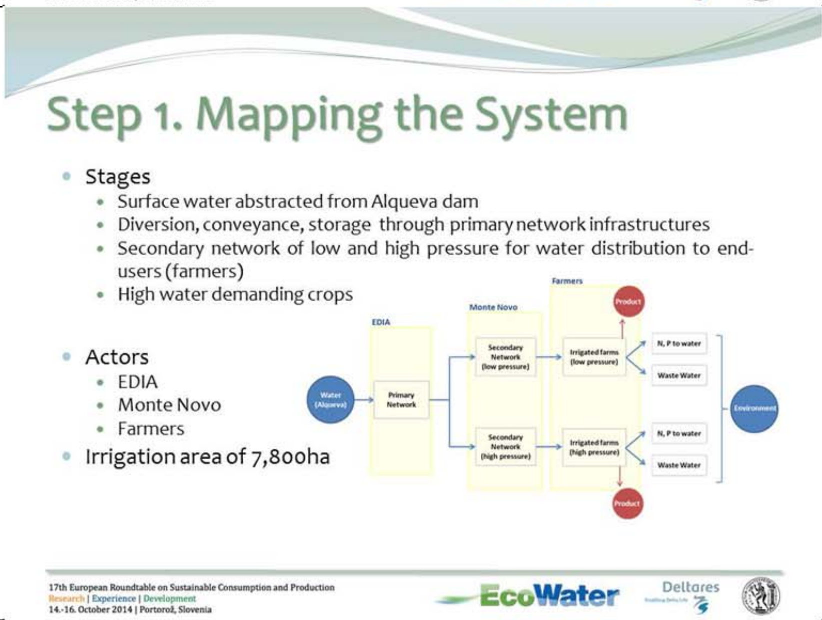

Step 1. Mapping the System
Stages
Surface water abstracted from Alqueva dam
Diversion, conveyance, storage through primary network infrastructures
Secondary network of low and high pressure for water distribution to end-users (farmers)
High water demanding crops
Actors
EDIA
Monte Novo
Farmers
Irrigation area of 7,800ha
EDIA
Monte Novo
Farmers
Water (Alqueva)
Primary Network
Secondary Network (low pressure)
Secondary Network (high pressure)
Irrigated farms (low pressure)
Irrigated farms (high pressure)
Product
N, P to water
Waste Water
Environment
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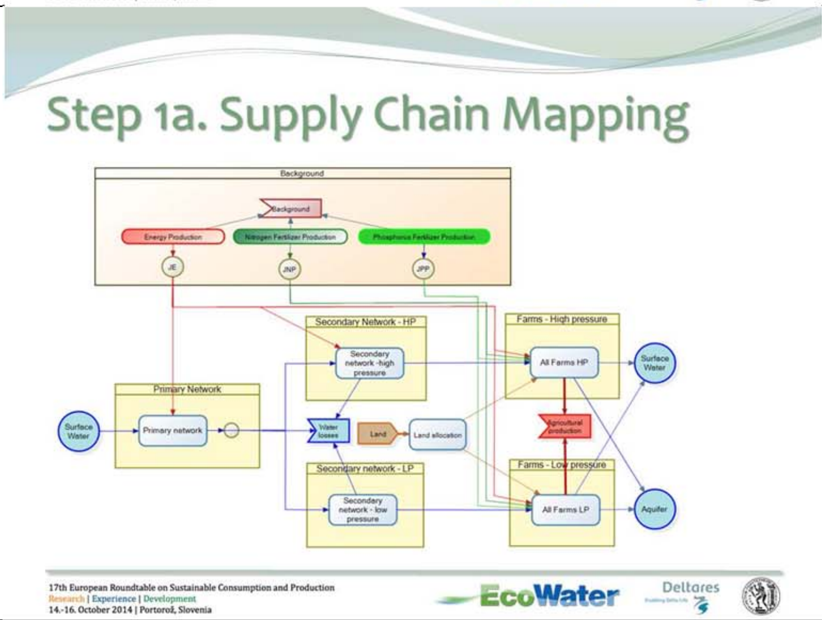

Step 1a. Supply Chain Mapping
Background
Energy Production
Nitrogen Fertilizer Production
Phosphorus Fertilizer Production
Secondary Network - HP
Secondary network -high pressure
Farms - High pressure
All Farms HP
Surface Water
Primary Network
Primary network
Water losses
Land
Land allocation
Agricultural production
Farms - Low pressure
Secondary network - LP
Secondary network - low pressure
All Farms LP
Aquifer
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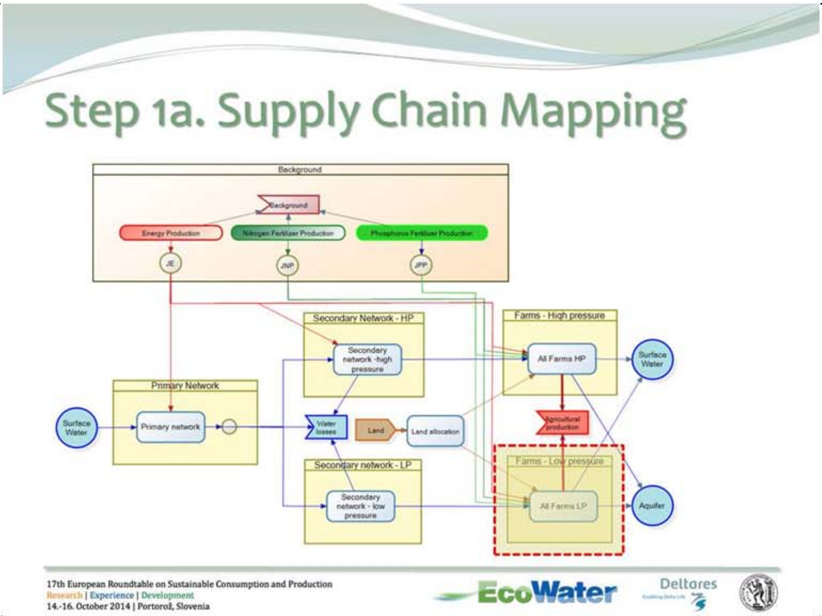

Step 1a. Supply Chain Mapping
Background
Energy Production
Nitrogen Fertilizer Production
Phosphorus Fertilizer Production
JE
JNP
JPP
Secondary Network - HP
Secondary network -high pressure
Farms - High pressure
All Farms HP
Surface Water
Primary Network
Primary network
Water losses
Land
Land allocation
Agricultural production
Secondary network - LP
Secondary network - low pressure
Farms - Low pressure
All Farms LP
Aquifer
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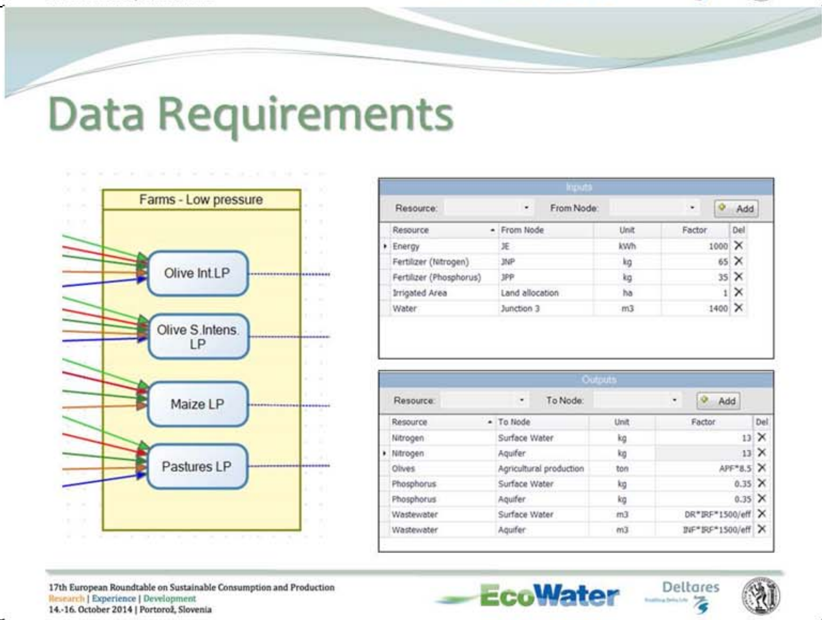

Data Requirements
Farms - Low pressure
Olive Int.LP
Olive S.Intens. LP
Maize LP
Pastures LP
Inputs
Resource: From Node: Add
Resource | From Node | Unit | Factor | Del
Energy | JE | kWh | 1000
Fertilizer (Nitrogen) | JNP | kg | 65
Fertilizer (Phosphorus) | JPP | kg | 35
Irrigated Area | Land allocation | ha | 1
Water | Junction 3 | m3 | 1400
Outputs
Resource: To Node: Add
Resource | To Node | Unit | Factor | Del
Nitrogen | Surface Water | kg | 13
Nitrogen | Aquifer | kg | 13
Olives | Agricultural production | ton | APF*8.5
Phosphorus | Surface Water | kg | 0.35
Phosphorus | Aquifer | kg | 0.35
Wastewater | Surface Water | m3 | DR*IRF*1500/eff
Wastewater | Aquifer | m3 | INF*IRF*1500/eff
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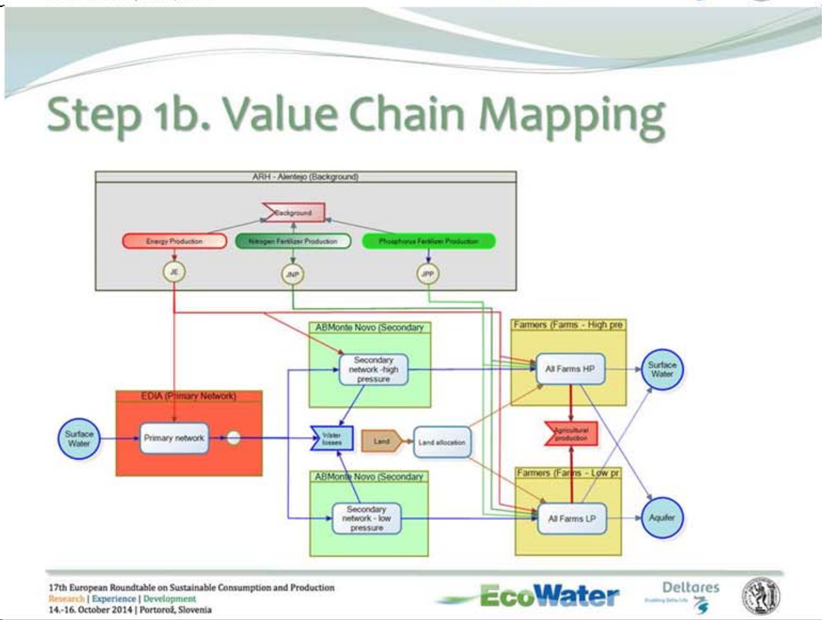

Step 1b. Value Chain Mapping
ARH - Alentejo (Background)
Background
Energy Production
Nitrogen Fertilizer Production
Phosphorus Fertilizer Production
JE
JNP
JPP
ABMonte Novo (Secondary
Secondary network -high pressure
Farmers (Farms - High pre
All Farms HP
Surface Water
EDIA (Primary Network)
Primary network
Water losses
Land
Land allocation
Agricultural production
ABMonte Novo (Secondary
Secondary network - low pressure
Farmers (Farms - Low pr
All Farms LP
Aquifer
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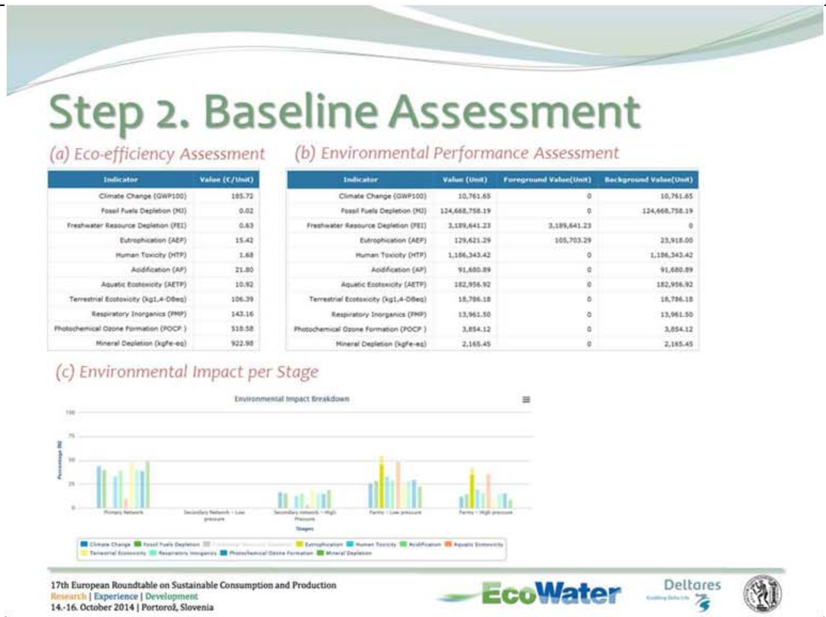

Indicator	Value (€/Unit)
Climate Change (GWP100)	185.72
Fossil Fuels Depletion (MJ)	0.02
Freshwater Resource Depletion (FEI)	0.63
Eutrophication (AEP)	15.42
Human Toxicity (HTP)	1.68
Acidification (AP)	21.80
Aquatic Ecotoxicity (AETP)	10.92
Terrestrial Ecotoxicity (kg1,4-DBeq)	106.39
Respiratory Inorganics (PMP)	143.16
Photochemical Ozone Formation (POCP)	518.58
Mineral Depletion (kgFe-eq)	922.98

Indicator	Value (Unit)	Foreground Value(Unit)	Background Value(Unit)
Climate Change (GWP100)	10,761.65	0	10,761.65
Fossil Fuels Depletion (MJ)	124,668,758.19	0	124,668,758.19
Freshwater Resource Depletion (FEI)	3,189,641.23	3,189,641.23	0
Eutrophication (AEP)	129,621.29	105,703.29	23,918.00
Human Toxicity (HTP)	1,186,343.42	0	1,186,343.42
Acidification (AP)	91,680.89	0	91,680.89
Aquatic Ecotoxicity (AETP)	182,956.92	0	182,956.92
Terrestrial Ecotoxicity (kg1,4-DBeq)	18,786.18	0	18,786.18
Respiratory Inorganics (PMP)	13,961.50	0	13,961.50
Photochemical Ozone Formation (POCP)	3,854.12	0	3,854.12
Mineral Depletion (kgFe-eq)	2,165.45	0	2,165.45

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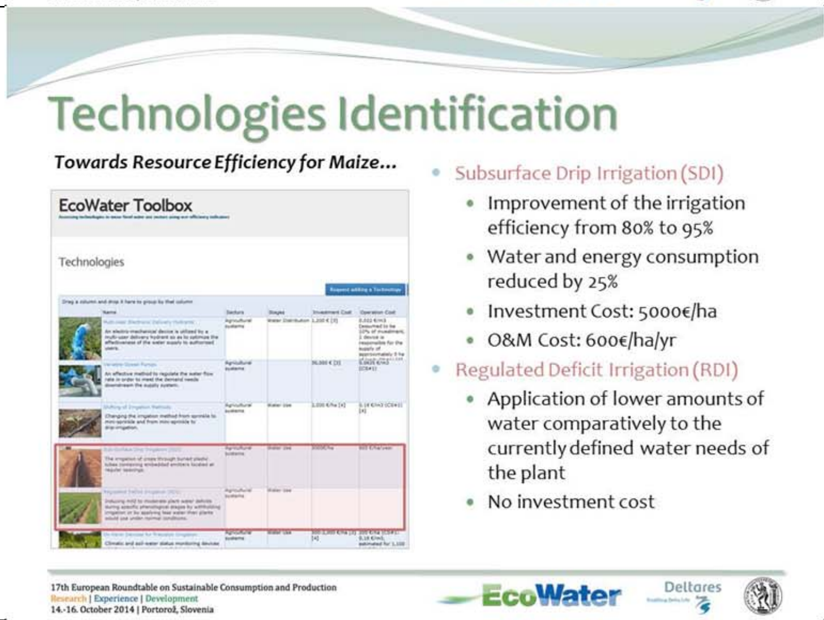

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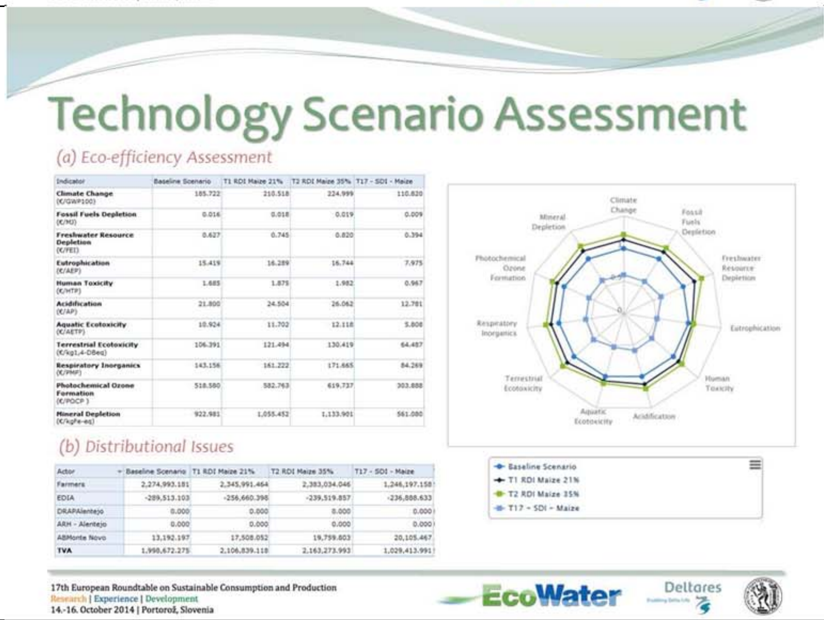

Indicator	Baseline Scenario	T1 RDI Maize 21%	T2 RDI Maize 35%	T17 - SDI - Maize
Climate Change (€/GWP100)	185.722	210.518	224.999	110.820
Fossil Fuels Depletion (€/MJ)	0.016	0.018	0.019	0.009
Freshwater Resource Depletion (€/FEI)	0.627	0.745	0.820	0.394
Eutrophication (€/AEP)	15.419	16.289	16.744	7.975
Human Toxicity (€/HTP)	1.685	1.875	1.982	0.967
Acidification (€/AP)	21.800	24.504	26.062	12.781
Aquatic Ecotoxicity (€/AETP)	10.924	11.702	12.118	5.808
Terrestrial Ecotoxicity (€/kg1,4-DBeq)	106.391	121.494	130.419	64.487
Respiratory Inorganics (€/PMF)	143.156	161.222	171.665	84.269
Photochemical Ozone Formation (€/POCP)	518.580	582.763	619.737	303.888
Mineral Depletion (€/kgFe-eq)	922.981	1,055.452	1,133.901	561.080

Actor	Baseline Scenario	T1 RDI Maize 21%	T2 RDI Maize 35%	T17 - SDI - Maize
Farmers	2,274,993.181	2,345,991.464	2,383,034.046	1,246,197.158
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TVA	1,998,672.275	2,106,839.118	2,163,273.993	1,029,413.991

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DHI
IVL Swedish Environmental Research Institute
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2.3 Facilitating multi-stakeholder discussions on improvement options through comparative eco-efficiency assessments

Les LEVIDOW[1]

[1] Open University

2.3.1 *Abstract*

Introduction

EU policy promotes eco-innovation to enhance resource efficiency as a means towards sustainable development. Informing such efforts, the EcoWater project develops and applies eco-efficiency indicators in diverse water-service systems in agricultural, urban and industrial sectors. The project's method compares the baseline situation with improvement options in order to facilitate decisions upgrading the whole-system value chain. This encompasses all relevant stages necessary to generate a product or service.

Concepts and methods for stakeholder discussions:

Optimal eco-efficiency improvements depend on stakeholders sharing knowledge and responsibility beyond current institutional boundaries (WBCSD, 2000). According to socio-technical transition theory, actors position themselves somewhere between current and potential future structures – by obeying, neglecting, bypassing and/or transforming the current structure. Each actor needs knowledge of other actors – their interpretive schemas, capacities, normative expectations, etc. They can develop the necessary knowledge and elaborate their future visions through scenario exercises, facilitated by an external agent such as a researcher (Grin et al., 2010). To facilitate such discussions, the EcoWater project analyses interactions among heterogeneous actors, especially water suppliers, water users and wastewater treatment facilities (EcoWater, 2012). For each case study, stakeholders were asked to provide data necessary for assessing whole-system eco-efficiency. Then they attended a workshop for comparing future options, as well as for identifying drivers and barriers, sometimes through a PESTLE-scenario analysis (Van der Heijden, 2005).

Results of discussions:

Relative to its overall sector, each case study represents relatively strong prospects for eco-efficiency improvements. Workshops discussed improvement options, their potential benefits, drivers and barriers – but with significant differences in emphasis. For some companies in large-scale industry, participants discussed potential cooperation across the value chain towards common solutions, for example: If a dairy plant adopts in-house wastewater treatment, then this would lower resource burdens within the plant but would bring minimal benefit from a whole-system perspective. In a manufacturing company a change in process would increase whole-system eco-efficiency, but the wastewater treatment plant would lose income. Each for different reasons, those problems warranted further discussion among

stakeholders (Levidow et al., 2014). In the case of textile-dyeing Small and Medium Enterprises, the discussion emphasised barriers from policy frameworks and uncertain markets. In an urban case study, the project team suggested numerous options for improvement, but workshop participants decided instead to discuss politically contentious options, which would be difficult to pursue within or beyond the EcoWater study. For an agricultural area facing groundwater depletion and water shortages, workshop participants initially discussed numerous options for water-use efficiency. But they soon focused instead on external sources of recycled water; this shift signals a weak institutional capacity for sharing responsibility towards common solutions.

Conclusion:

By assessing whole-system eco-efficiency, the EcoWater method has facilitated multi-stakeholder discussion on investment options. Prior discussion encouraged stakeholders' attendance at a case-study workshop where they learned more about each other's perspectives and future scenarios. Some workshops helped participants to envisage ways of sharing greater responsibility towards whole-system improvements. But in other cases the discussion reproduced current structures and their boundaries. Stronger incentives and opportunities are necessary to overcome such limitations.

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Keywords

Resource efficiency, whole-system assessment, eco-efficiency, scenario exercises

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2.3.2 Presentation

(1)

Facilitating Multi-stakeholder Discussions on Eco-innovation for Process Upgrading

EcoWater

Les Levidow, Michiel Blind, Åsa Nilsson, Sara Alongi Skenhall, Irina Ribarova, Albena Popova, Peyo Stanchev

ERSCP conference, 14-16 October 2014, Portorož

(2)

Assessing options for eco-innovation

- For many years, industry has sought to enhance sustainability through eco-innovation, combining ecological and economic benefits as a win-win strategy (OECD, 2012).
- To compare benefits of options for eco-innovation, the eco-efficiency concept has helped to anticipate or measure improvements in resource efficiency alongside economic advantage. But most assessments have narrowly focused on a production site within a company.
- Recently some companies have shown interest in whole-system analysis, i.e. encompassing the value chain of an entire production process. This encompasses all inputs, valuable products, waste, its treatment, etc.
- Also called the meso level, which 'is the most challenging from the point of view of gathering evidence, as it requires information from many agents' (Reid and Miedzinski, 2008 Technopolis).

(3)

Questions

- Looking beyond a production site, what are options for eco-innovation to enhance resource efficiency within an entire process across the whole-system (meso-level) value-chain?
- What are drivers, barriers and trade-offs for specific options?
- How can multi-stakeholder discussions clarify those issues, towards better decision-making?

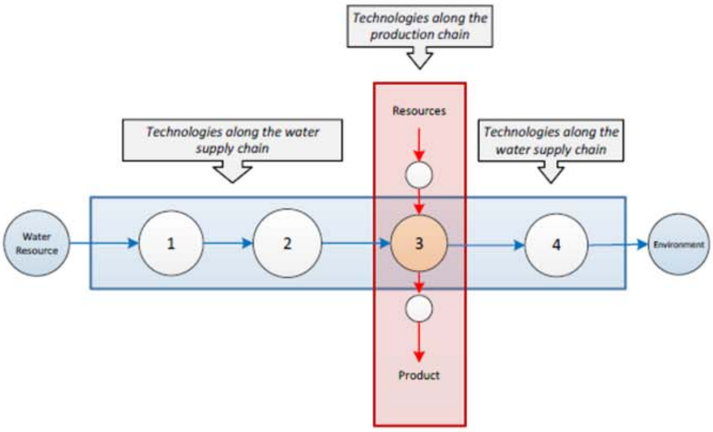
(4)

EcoWater project: concepts

- FP7 project,
  'EcoWater: Meso-level eco-efficiency indicators to assess technologies & their uptake in water use sectors'.
- Project aims: to assess the eco-efficiency of various options for innovative practices (including technologies), to compare their relative benefits, to analyse factors influencing decisions to adopt such practices, to inform better decision-making, and to inform policy frameworks which could promote such decisions.
- Meso level (whole system) = interactions among heterogeneous actors, e.g. between water-services users and providers.
- Eco-efficiency = ratio between economic benefit/resource burdens; economic benefit = total value added (TVA), i.e. income minus costs.
- Eco-efficiency indicators help to compare options for innovative practices, including technology adoption.
- 'Water-service system' describes any system which makes water suitable and available for specific purposes, e.g. drinking, cooling, industrial processing, irrigation, etc.

(5)

Potential improvement sites along the whole-system (meso-level) value chain



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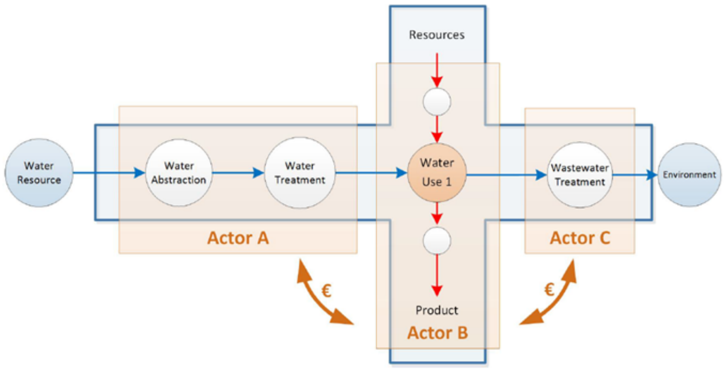
Whole system: flow of resources and economic value, interactions among actors



(7)

Upgrading of process and/or product

Process or product? Process upgrading uses resources in more efficient ways, while production-chain upgrading increases the market value of products.

A firm can transform its internal processes by redesigning them on the basis of new environmental goals. Upgrading 'may induce the firm to develop new functions and play a new role in its value chain' (De Marchi et al., 2013).

Companies willing to cooperate with the EcoWater project had already made significant investment in eco-innovation for upgrading production processes, relative to their respective industrial sector.

Impetus has come from companies' environmental policies, as well as from external drivers such as future higher costs and resource scarcity, beyond legislative requirements.

This paper draws on three case studies led by other partners (co-authors) to analyse multi-stakeholder interactions.

(8)

Multi-stakeholder scenario exercises

- Case-study workshop discussions identified PESTLE parameters (Political, Economic, Social, Technical. Legal and Environmental) likely to influence future decisions on eco-innovation.
- More generally, scenario-analysis exercises can clarify options for eco-innovation pathways.
- These exercises can also shape stakeholders' expectations, formulate transition routes and develop strategies to realise them.
  Different agents interact because they find common interests and/or a mutual dependence for jointly achieving their objectives (Grin et al., 2010).
- Multi-stakeholder scenario workshops potentially facilitate broader visions beyond current constraints.

(9)

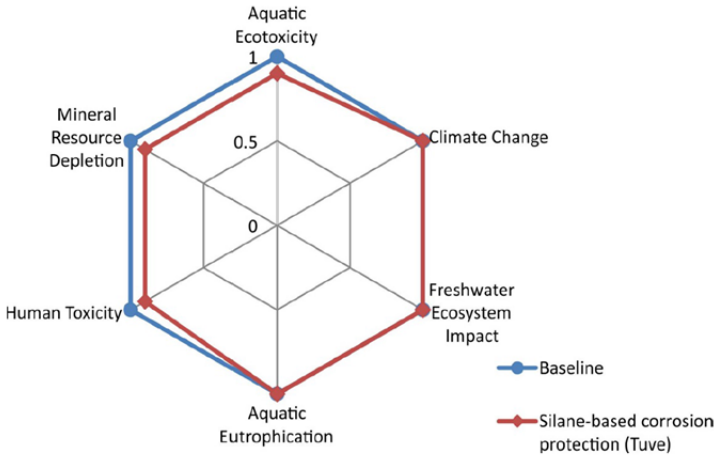
Volvo Trucks case:

corrosion-protection process

- Sector has prioritised fuel/energy-efficiency in operating vehicles; Volvo has gone further in upgrading the process.
- Volvo Group's sustainability report: 'a resource-efficiency approach is well integrated in our culture and is an important priority ahead'. Operations attempt to minimise energy use, recycle materials and install closed-process water systems.
- Ecowater case study investigated potential improvements in corrosion-protection process.
- Silane-based process could replace phosphating technology. Novel technology lowers costs, resource inputs, pollutants and WWT.
- Multi-stakeholder workshop discussed assessment of meso-level eco-efficiency and value-chain effects.

(10)

Silane-based option compared with baseline (phosphating)



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TVA increases but is redistributed across the meso-level value chain

Value-chain stage	Kretslopp & Vatten: Water supply	Volvo Trucks: Water supply, use and WWT	Stena Recycling: WWT	Eco-efficiency of total value chain
Economic /Environ-mental parameters	Econ. - Env. +	Econ. + Env. +	Econ. - Env. +	Increase

(12)

Volvo workshop conclusions

Stakeholders’ conclusions:

- Technologies should be selected for improving the whole system, not only in the specific processes where they are implemented, in order to avoid sub-optimal investment.
- Sub-optimisation can be more easily avoided through stakeholder cooperation in evaluating the overall system.
- Organization of the different players towards a common goal can increase cooperation among actors that share a mutual interest in environmental protection.

• Meso-level evaluation stimulated discussion.

It also gave stakeholders greater insight into where the largest improvements can be made, both environmentally and economically, and how they may influence each other within a common meso-level system.

(13)

Energy cogeneration

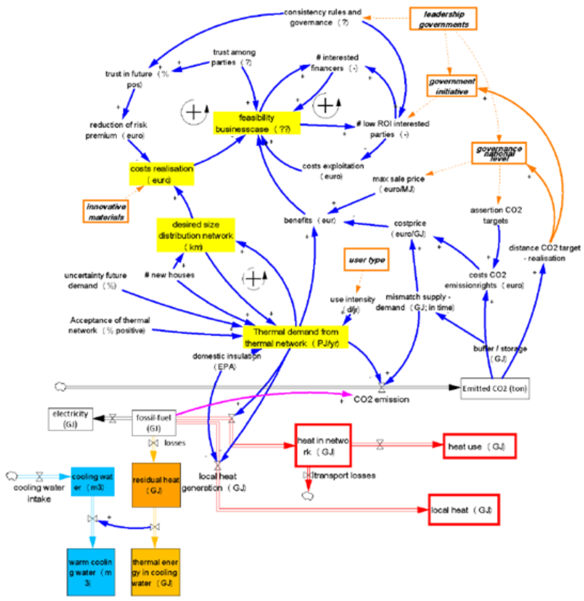
- Energy cogeneration, also known as CHP (Combined Heat & Power), has higher energy efficiency than separate production of each component, provided that there is adequate demand for both power and heat.
- Key factors in useable heat: use-time variations and temperature options.
- How to match variable demand with supply?

(14)

Workshop focus: thermal network?

- Plant seeks a new use for excess heat at its current temperature in a larger meso-level value chain.
- EcoWater study investigated options at the Diemen 33 cogeneration plant.
- Multi-stakeholder workshop discussed the necessary conditions for establishing a thermal network.
  District heating systems had been installed in a newly built neighbourhoods in the Netherlands (and elsewhere), but there was little residential building activity near the plant.
  So this solution would replace previous investment in heating systems.
- Workshop also discussed drivers and barriers, whose interactions were depicted in an influence diagram.

(15)



(16)

Options for matching supply/demand

- Company's commitment to extend district heating would need political confidence in future favourable conditions, especially through 'consistent governance for a 30-50 year period'. Necessary conditions: a heat price equal to gas; and CO_2 emission credits to be made more expensive, so that low-carbon energy becomes more competitive.
- Under foreseeable circumstances, the company will not link the plant with a district-heating.
- Considers options to match variations in heat demand.
- Those judgements reveal tensions between:
  Micro-level priority: to maximise profit, which comes mainly from electricity as the most lucrative product.
  Meso-level priorities: to maximise usable energy and consequent income while also minimising resource burdens.

(17)

Sofia urban water system

- Sofia's urban water system is sourced mainly from the Iskar reservoir at a higher altitude than the city. Water is transported by pressurized water mains to the WTP, situated around 60m lower than the Iskar reservoir. Thus there is a huge potential for hydro-energy at the plant's inlet.
- Multi-stakeholder workshop had 12 participants representing national and local institutions.
- Stakeholders decided to focus discussion on two options:
- a pressure-reduction turbine, through a small hydropower plant along the pipe feeding the WTP; and
- heat recovery from households, through pumps recovering heat from the sewerage system

(18)

Barrier: unclear legal framework

Discussion of PESTLE factors identified potential stakeholder conflicts over the distribution of costs and benefits.
Who would benefit from the extra energy or income – only the water-utility operator? or also citizens through lower water tariffs?

This issue was seen as jointly political-legal, i.e. an unclear legal framework for water management.

If these institutional issues are not clarified, then the improvement potential will be lost, according to participants

(19)

Conclusion 1: facilitating discussions

- EcoWater method facilitated multi-stakeholder discussion on options for upgrading the production process, by bringing together information from several actors (cf. Technopolis, 2008).
- Method for meso-level assessments of eco-innovation within a water-service system.
- Prior discussion encouraged attendance at case-study workshops where stakeholders learned more about each others' perspectives, improvement options and future scenarios.
- Workshops helped participants to envisage ways of sharing knowledge and greater responsibility towards better options (cf. Grin et al., 2010).

(20)

Conclusion 2: 'win-win' tensions

Eco-innovation is meant to combine ecological and economic benefits for 'win-win' solutions (OECD, 2012).

Yet the assessments identified tensions – among various aims, resource burdens, system levels (meso vs micro), economic beneficiaries and timescales.

In the case studies:

- Vehicle corrosion-protection: only the dominant stakeholder gains economically.
- Cogeneration: insufficient incentive to invest in district heating.
- Urban-water energy-recovery: stakeholders' entitlement to the economic benefits remains ambiguous.

Project's meso-level method can help to assess better options, identify their tensions, reach joint responsibilities and pursue more conducive policy frameworks for eco-innovation.

<table>
<tr><td>(21)</td><td>
<table>
<tr><th>Resource burdens</th><th>Energy input in production process</th><th>Energy necessary to manage hazards</th><th>Eco-innovation option and tensions (example)</th></tr>
<tr><td>Water-service roles</td><td>in main company</td><td>in main and/or WWT company</td><td>in main company</td></tr>
<tr><td>1. Dairy: Milk-powder prodn extracts milky water needing disposal</td><td>Water removal from milk</td><td>Treating WW residues to avoid eutrophication</td><td>In-house anaerobic WWT would substitute renewable energy and reduce the dairy's GHG emissions. But would bring minimal whole-system benefits, by shifting biogas from the outside to the dairy.</td></tr>
<tr><td>2. Trucks: Corrosion-protection needs water to carry inputs, to heat the process baths and to remove wastes.</td><td>Water abstraction, purification and circulation. Hot water for high-temperature chemical process.</td><td>Treating organic materials which would cause eutrophication. Removing heavy metals.</td><td>Silane-based room-temperature process would reduce water and energy use; also would replace heavy metals and so avoid hazardous sludge. But lower-volume WW would lower the value-added for WWT.</td></tr>
<tr><td>3. Cogeneration (electricity + heat): Requires cooling-water to remove heat.</td><td>Water abstraction to cool the electricity-condensing point</td><td>Pumping to remove cooling-water, whose emissions can cause a public health hazard.</td><td>Higher-temperature condensing-point would need less energy for water pumps and produce more flexibly useful heat for industry, but would increase costs and reduce electricity income. District-heating system could use lower-temperature heat but depends on expensive investment in a heat network and a long-term policy commitment.</td></tr>
<tr><td>4. Municipal water system Requires energy for WWT, water purification and heating</td><td>Water purification and heating</td><td>Treating WW and sludge</td><td>Hydropower plant (along the pipe feeding the WT plant) would substitute renewable energy for fossil fuel. But the benefits-distribution remain legally ambiguous.</td></tr>
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2.4 Assessing the eco-efficiency of a meso-scale agricultural water system in Southern Italy

Mladen TODOROVIC[1], Andi MEHMETI[1] and Alessandra SCARDIGNO[1]

[1] CIHEAM - Mediterranean Agronomic Institute of Bari, Italy

2.4.1 Abstract

The eco-efficiency of the agricultural water sector encompasses both the ecological and economic dimensions of sustainable agriculture and promotes a simple integrated concept of achieving more agricultural outputs, in terms of income, with less inputs of land, water, energy, nutrients, labour, or capital. This work aims at the assessment of eco-efficiency of the irrigation district Sinistra Ofanto, located in Apulia region, South-East Italy.

The study area represented a meso-scale agricultural water system which covered about 39,000 ha of agricultural land characterized by three specific water supply chains and corresponding irrigation zones. A model was developed through the case study inventory analysis which entails the data about flows entering the system and also the direct and indirect emissions to the environment from the operations of the study system itself throughout the life cycle. The assessment was performed for a normal and a dry year, corresponding to annual precipitation of 514 and 420 mm, respectively. The on-field agronomic and water management practices, water delivery and economic data referred to year 2007. Hence, the baseline scenario adopted the application of deficit irrigation strategy for artichoke, olives, orchards and sugar beet, and full irrigation for other crops except wheat which was grown under rainfed conditions. The eco-efficiency was estimated as a ratio between the economic performances of the system and produced environmental impacts. Economic performances were expressed in terms of Value Added from the agricultural land use and adopted management practices, whereas the environmental performance followed a life-cycle oriented approach using 11 midpoint environmental impact categories which were selected as the more representative ones for the environmental assessment of the system. The analysis was performed by using the new modelling tools, Environmental Analysis Tool (SEAT) and Economic Value chain Analysis Tool (EVAT), both developed within the frame of EcoWater project (http://environ.chemeng.ntua.gr/ecowater/). The environmental impacts on a cluster (crop) level was performed on the basis of the irrigation (water) supply to crops and corresponding agronomic practices. The eco-efficiency of the system greatly depends upon the yields achieved (water use), market prices, the location and sources of water (surface or ground), the hydraulic characteristics of water delivery and distribution network, landscape, cropping pattern and adopted irrigation method. The overall results indicated that the system performances are strongly affected by a non-controlled water withdrawal from the aquifers which is particularly relevant under dry year

conditions. This increases the environmental burdens and requires the uptake of new technological solutions for the enhancement of eco-efficiency of Sinistra Ofanto irrigation scheme.

The system has relevant potential for the improvement of environmental performance. The most relevant solutions are the implementation of on-farm water saving technologies (drip and subsurface drip irrigation methods), the substitution of diesel engine pumps with electric pumps for groundwater abstraction and the adoption of new water pricing policies.

Keywords
Irrigation, economic performances, environmental impact, water saving technologies, sustainable agriculture.

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2.4.2 Presentation

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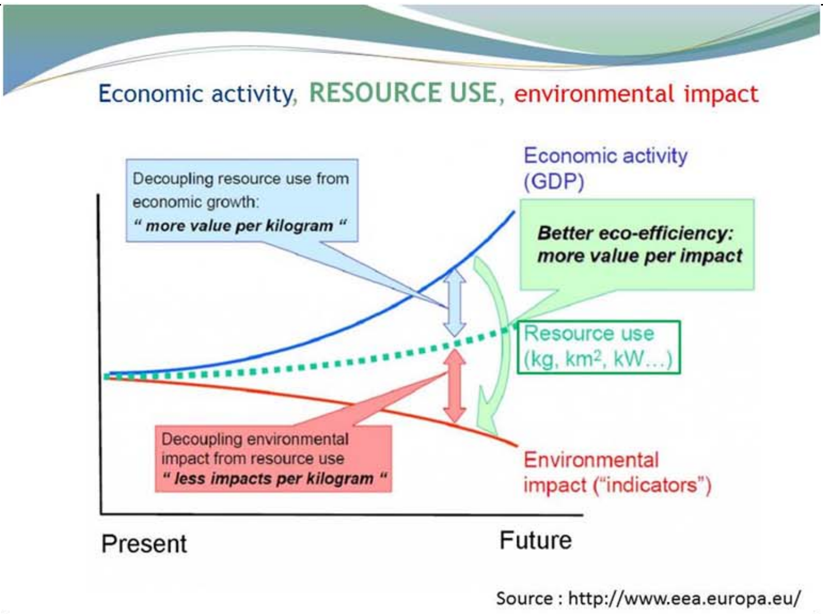
<tr><td>(2)</td><td>
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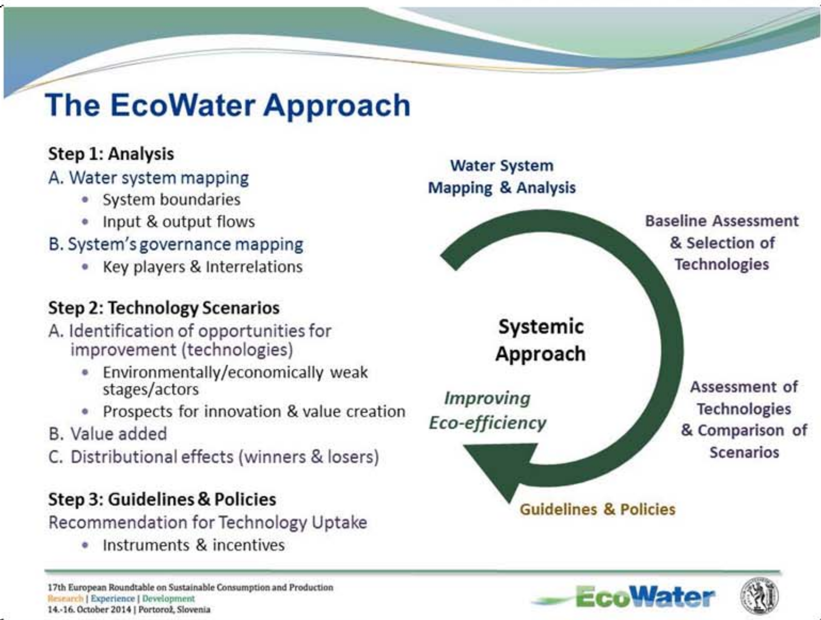
<tr><td>(3)</td><td>
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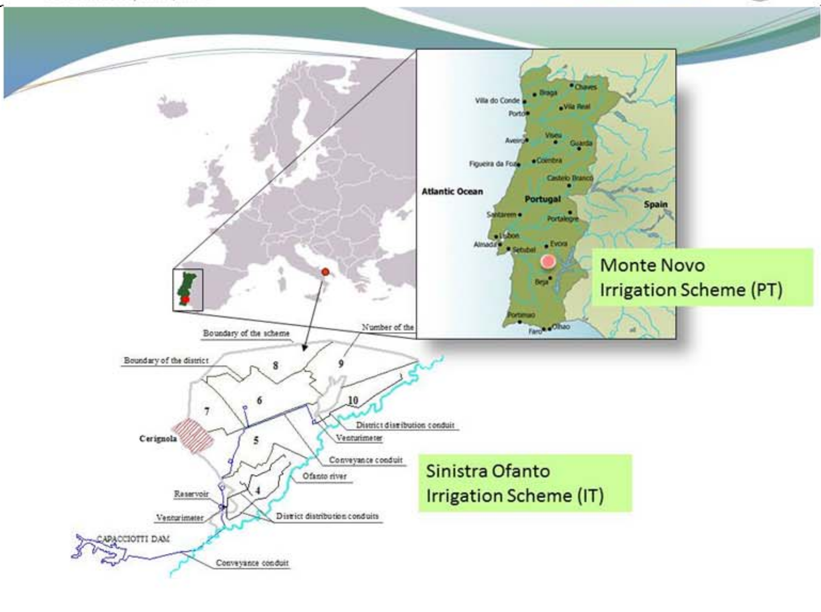
<tr><td>(4)</td><td>
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Case study area: Sinistra Ofanto irrigation system

- Area: 39,000 Ha
- Number of water users: 27,251
- On-Demand
- 14 operational districts
- 18,500 farms, with an average size of 2.0 ha

Irrigation zones:

District 1-2-3: Pumping distribution system

Upper Zone: Lifting+Gravity distribution system

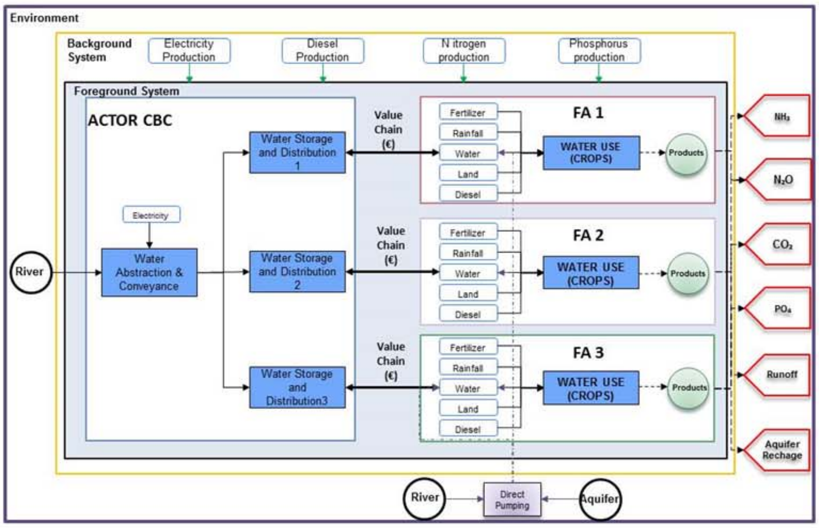
Lower Zone: Gravity fed distribution system

Cropping pattern [Area, ha]

Crop	Zone 1	Zone 2	Zone 3
Olives	60	3656	3619
Vineyards	98	3834	10571
Wheat	2218	2605	1943
Orchards	67	13	3147

(6)

System Mapping (Holistic Approach)



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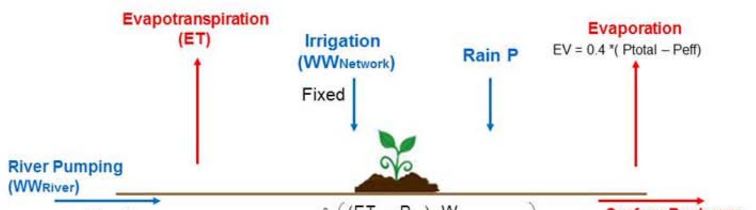
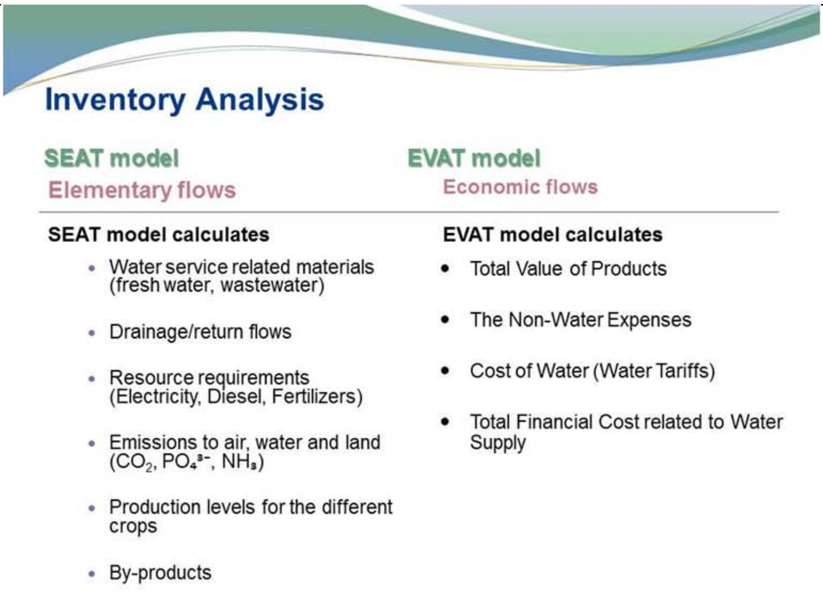
Soil-Water-Balance



$$WW = \frac{WD}{\prod_{j=1}^{m} EFF_j} = \frac{\sum_{i=1}^{n}\left(\frac{(ET_c - P_{eff}) \cdot W_{crop}}{EFF_{app}} \cdot A_{crop}\right)_i}{\prod_{j=1}^{m} EFF_j}$$

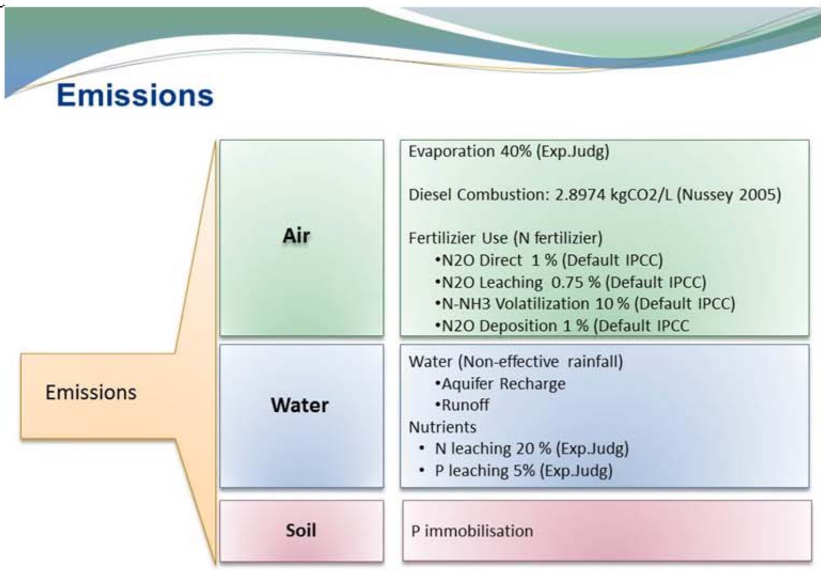
$$WW_{Aquifer} = WW - WW_{Network} - WW_{River}$$

(8)



Inventory Analysis
SEAT model
Elementary flows
EVAT model
Economic flows
SEAT model calculates
Water service related materials (fresh water, wastewater)
Drainage/return flows
Resource requirements (Electricity, Diesel, Fertilizers)
Emissions to air, water and land (CO_2, PO_4^{3-}, NH_3)
Production levels for the different crops
By-products
EVAT model calculates
Total Value of Products
The Non-Water Expenses
Cost of Water (Water Tariffs)
Total Financial Cost related to Water Supply

(9)

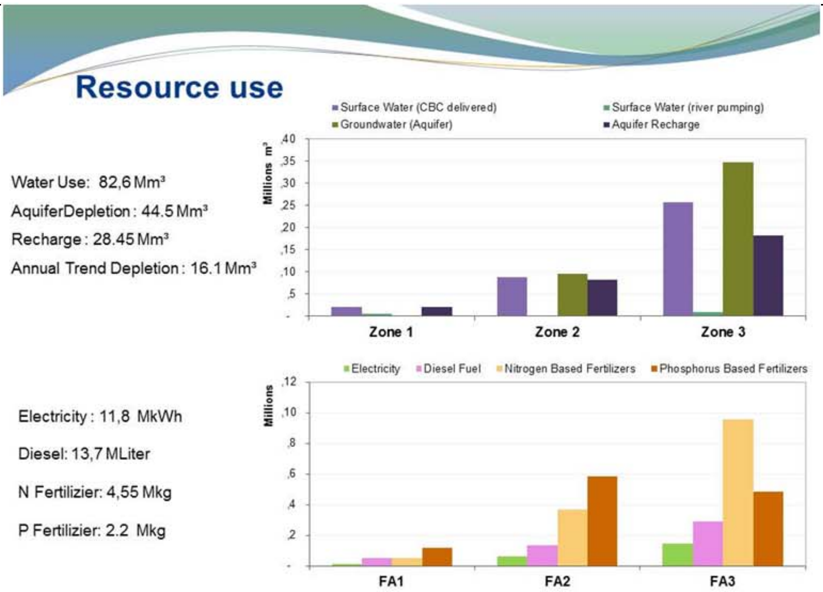


Emissions
Emissions
Air
Evaporation 40% (Exp.Judg)
Diesel Combustion: 2.8974 kgCO2/L (Nussey 2005)
Fertilizier Use (N fertilizier)
•N2O Direct 1 % (Default IPCC)
•N2O Leaching 0.75 % (Default IPCC)
•N-NH3 Volatilization 10 % (Default IPCC)
•N2O Deposition 1 % (Default IPCC
Water
Water (Non-effective rainfall)
•Aquifer Recharge
•Runoff
Nutrients
• N leaching 20 % (Exp.Judg)
• P leaching 5% (Exp.Judg)
Soil
P immobilisation

(10)

RESULTS AND DISCUSSION

(11)



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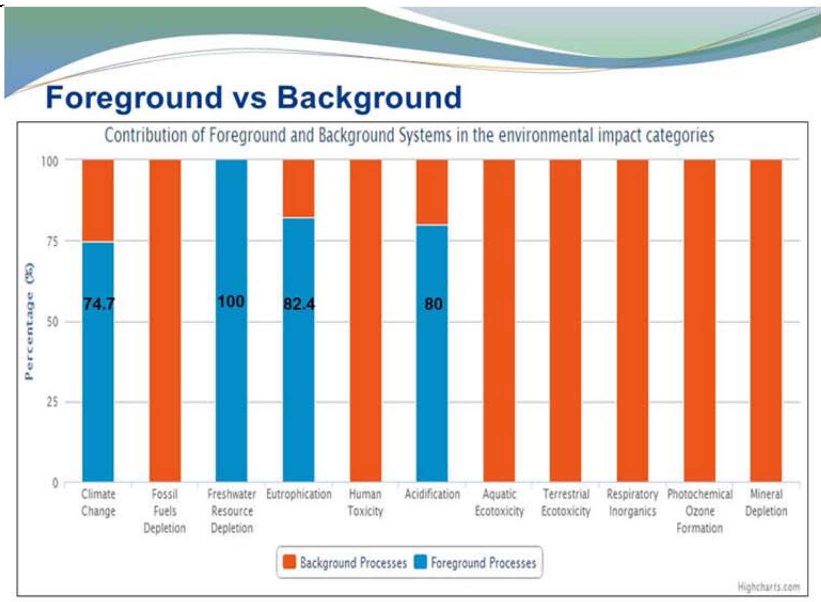
Environmental Impact Indicators (Whole System)

Indicator	Value (Unit)	Foreground Value (Unit)	Background Value(Unit)
Climate Change (tCO2eq)	88,976	66,470	22,505
Fossil Fuels Depletion (kg oil,eq)	19,464,496	0	19,464,496
Freshwater Resource Depletion (m3)	13,623,492	13,623,492	0
Eutrophication (kgPO4eq)	885,660	729,687	155,974
Human Toxicity (kg1,4-DBeq)	4,846,242	0	4,846,242
Acidification (kgSO2eq)	1,168,089	934,331	233,758
Aquatic Ecotoxicity (kg1,4-DBeq)	1,295,712	0	1,295,712
Terrestrial Ecotoxicity (kg1,4-DBeq)	24,882	0	24,882
Respiratory Inorganics (kgPM10,eq)	32,069	0	32,069
Photochemical Ozone Formation (kgC2H4,eq)	11,449	0	11,449
Mineral Depletion (kgFe-eq)	12,075	0	12,075

(13)



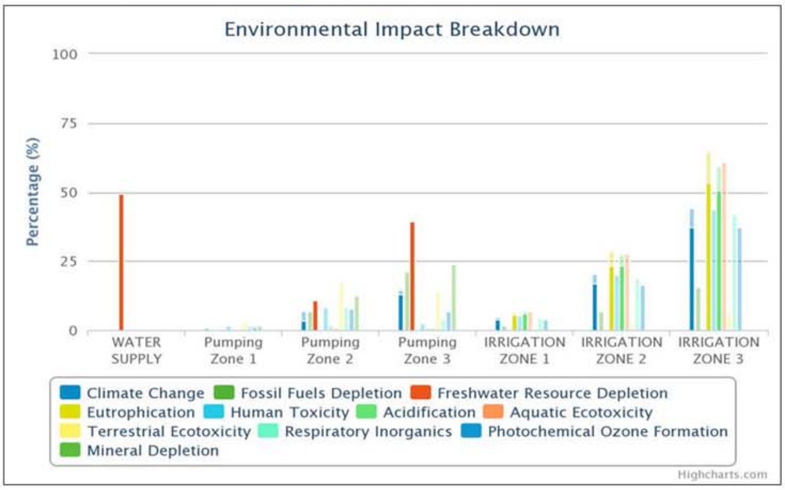
(14)

Environmental Impact Indicators (Whole System)

Indicator	Type I Indicator (per kg product)	Type II Indicator (per m^3 water used)
Climate Change (tCO2eq)	0.14	0.0011
Fossil Fuels Depletion (kg oil,$_{eq}$)	30.94	0.2354
Freshwater Resource Depletion (m^3)	21.65	0.1648
Eutrophication (kgPO_4eq)	1.41	0.0107
Human Toxicity (kg1,4-DBeq)	7.70	0.0586
Acidification (kgSO_2eq)	1.86	0.0141
Aquatic Ecotoxicity (kg1,4-DBeq)	2.06	0.0157
Terrestrial Ecotoxicity (kg1,4-DBeq)	0.04	0.0003
Respiratory Inorganics (kgPM10,eq)	0.05	0.0004
Photochemical Ozone Formation (kgC_2H_4,eq)	0.02	0.0001
Mineral Depletion (kgFe-eq)	0.02	0.0001

(15)

Environmental Impact Breakdown



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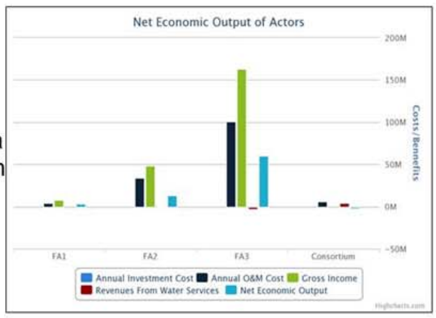
Economic Assessment

Total Value Added = 99,676,246 €

Total Value Added = 1.15 €/m³

Highest benefits FA3 with 2936 €/ha due more profitable cropping pattern and greater irrigation water supply.



Total Value Added = *f (Market prices, irrigation input (yield), cropping pattern)*

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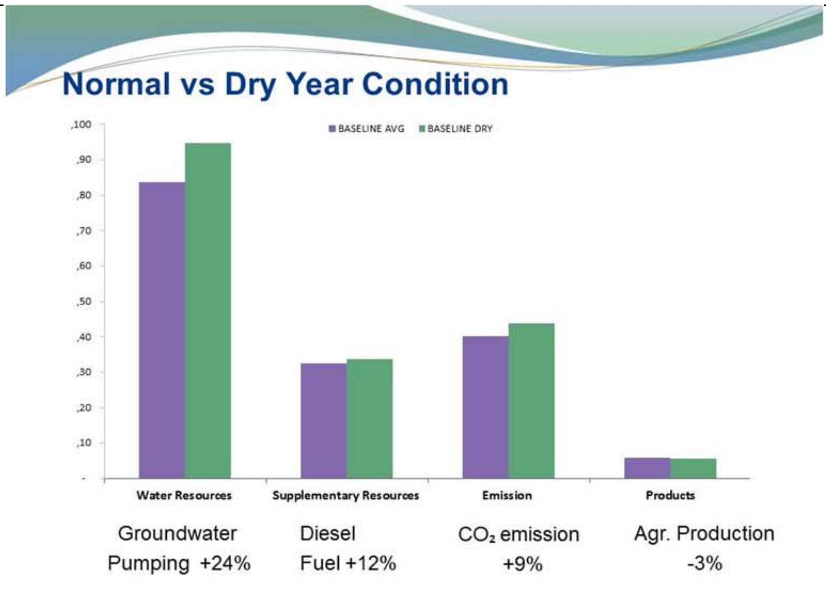

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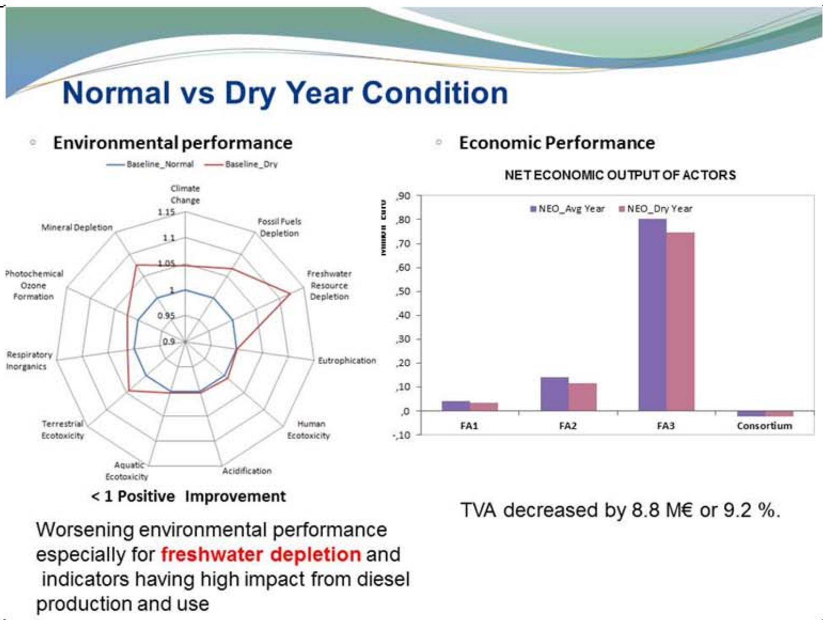

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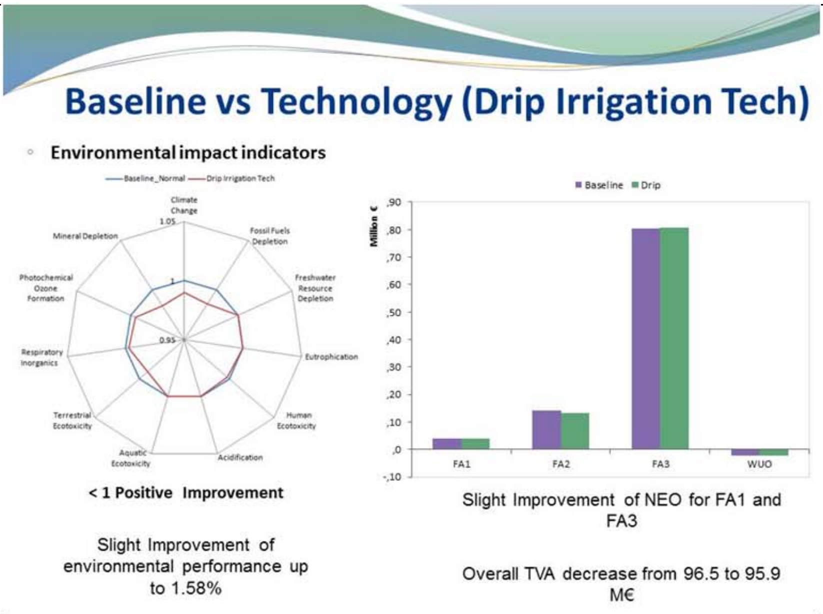
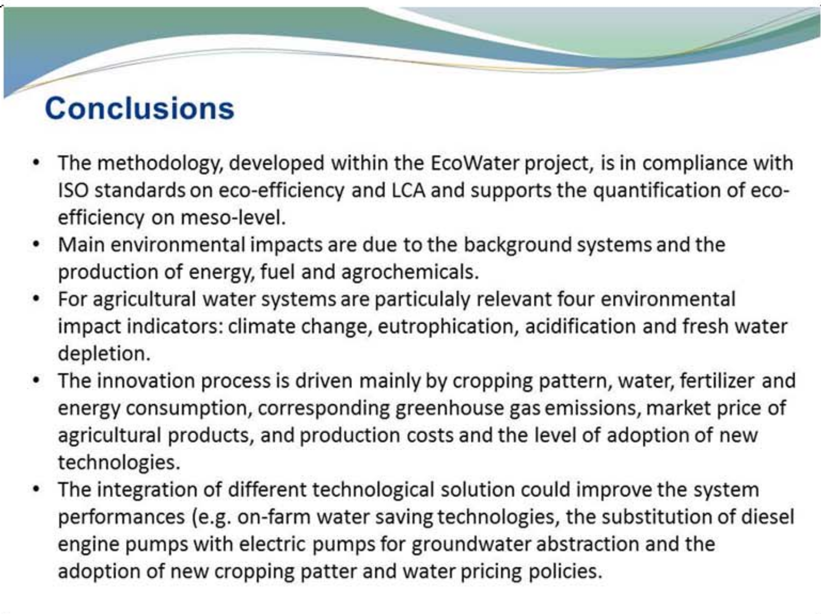
Normal vs Dry Year Condition (EE indicators)

Indicator	Unit	Baseline (Normal Year)	Baseline (Dry Year)	Change %
Climate Change	$€/tCO_2eq$	1,081.1	938.79	-13.2%
Fossil fuels depletion	€/MJ	4.9	4.20	-14.8%
Freshwater resource depletion	$€/m^3$	7.0	5.68	-19.02%
Eutrophication	$€/kgPO_4^{-3},eq$	109.0	99.00	-9.18%
Human toxicity	€/kg1,4-DBeq	19.9	17.93	-9.93%
Acidification	$€/kgSO_{2-},eq$	82.6	74.88	-9.38%
Aquatic Ecotoxicity	€/kg1,4-DBeq	74.5	67.50	-9.39%
Terrestrial Ecotoxicity	€/kg1,4-DBeq	3,866.7	3364.56	-12.99%
Respiratory inorganics	$€/kgPM_{10},eq$	3,007.7	2700.11	-10.23%
Photochemical ozone formation	$€/kgC_2H_4,eq$	8,417.9	7483.65	-11.10%
Minerals depletion	€/kg Fe-eq	7,948.3	6715.48	-15.51%

(20)


Baseline vs Technology (Drip Irrigation Tech)
Environmental impact indicators
Baseline_Normal
Drip Irrigation Tech
Climate Change
1.05
1
0.95
Fossil Fuels Depletion
Freshwater Resource Depletion
Eutrophication
Human Ecotoxicity
Acidification
Aquatic Ecotoxicity
Terrestrial Ecotoxicity
Respiratory Inorganics
Photochemical Ozone Formation
Mineral Depletion
< 1 Positive Improvement
Slight Improvement of environmental performance up to 1.58%
Baseline
Drip
Million €
,90
,80
,70
,60
,50
,40
,30
,20
,10
,0
-,10
FA1
FA2
FA3
WUO
Slight Improvement of NEO for FA1 and FA3
Overall TVA decrease from 96.5 to 95.9 M€

(21)


Conclusions
• The methodology, developed within the EcoWater project, is in compliance with ISO standards on eco-efficiency and LCA and supports the quantification of eco-efficiency on meso-level.
• Main environmental impacts are due to the background systems and the production of energy, fuel and agrochemicals.
• For agricultural water systems are particulaly relevant four environmental impact indicators: climate change, eutrophication, acidification and fresh water depletion.
• The innovation process is driven mainly by cropping pattern, water, fertilizer and energy consumption, corresponding greenhouse gas emissions, market price of agricultural products, and production costs and the level of adoption of new technologies.
• The integration of different technological solution could improve the system performances (e.g. on-farm water saving technologies, the substitution of diesel engine pumps with electric pumps for groundwater abstraction and the adoption of new cropping patter and water pricing policies.

(22)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IVL Swedish Environmental Research Institute

2.5 Eco-efficiency assessment in the agricultural sector: the Monto novo irrigation perimeter, Portugal

Rodrigo MAIA[1] and Cristina SILVA[1]

[1] FEUP - Faculty of Engineering of the University of Porto

2.5.1 Abstract

The Monto Novo public irrigation perimeter, located in the southern region of Portugal is part of the Alqueva Multi-purpose Project, with more than 115.000ha of irrigation beneficial area. Besides being the most important investment ever done in the Alentejo region, it is also a challenge for the regional renewal and necessary social and economic development. In a region dedicated, for decades, to rainfed agriculture, the new challenge created by the Alqueva reservoir, the largest artificial surface mass of water in Europe, creates a completely different setting for the future. In fact, for the last 15 years, the Alentejo region has been experiencing a complete change in the agricultural patterns going from low to highly water demanding crops like maize and pastures.

In 2009, the Monte Novo irrigation perimeter, located in the northern part of the Alqueva irrigation system, started operating with more than 7.700ha of irrigation beneficial area. This irrigation perimeter is still being managed by EDIA – “Empresa de Desenvolvimento e Infra-Estruturas do Alqueva”, the responsible organisation for the primary water supply system to the irrigation perimeters of the region, until the Farmers’ Association takes the lead with responsibilities of: (i) ensuring the operation and maintenance of hydro-agricultural development works; (ii) setting the watering schedule; and (iii) ensuring the collection of taxes for operation and maintenance, and manage the revenues. According to 2012 data, almost 5.000ha were already being irrigated with water. Low water tariffs fixed by law contributed to that with increasing values until 2017, when the total water price is to be charged to farmers. The subsidized water pricing policy aimed at fomenting the transition from rainfed agricultural practices to irrigation. The Monte Novo irrigation perimeter is part of the new paradigm set for the Alentejo region, which focuses on new economic activities, embracing new standards in innovation and technology.

In the context of an increasing commitment to water efficiency in the EU policy and in the current research framework, the EcoWater project has been focusing on eco-efficiency assessment, which goal is to attain economic and environmental improvement, promoting the comparison between different case studies in the different economic sectors. In the agricultural sector, the Monte Novo case study targets the new agricultural paradigm in course of implementation in the Alentejo region, focusing on the assessment of eco-efficiency for both the baseline scenario and a set of potential new technologies that would (i) be resource efficient, (ii) be pollution preventing

and/or (iii) would enhance circular economy.

Taking into account the performed evaluation of the baseline scenario, potential new technologies/innovations were selected and assessed based on stakeholders’ involvement and perceptions (e.g. drip irrigation and biological production). The results to be presented will focus on the comparison between each of the proposed innovative technologies’ performance and the baseline scenario. The methodology will highlight the environmentally weak stages and the potential needed investments, in order to facilitate stakeholders’ decisions. The set of eco-efficiency indicators evaluated will be complemented with an economic performance, leading to some policy recommendations on technology uptake.

Keywords
Eco-efficiency assessment, economic performance, value chain optimization

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Prof. MAIA, Rodrigo; FEUP - Faculty of Engineering of the University of Porto
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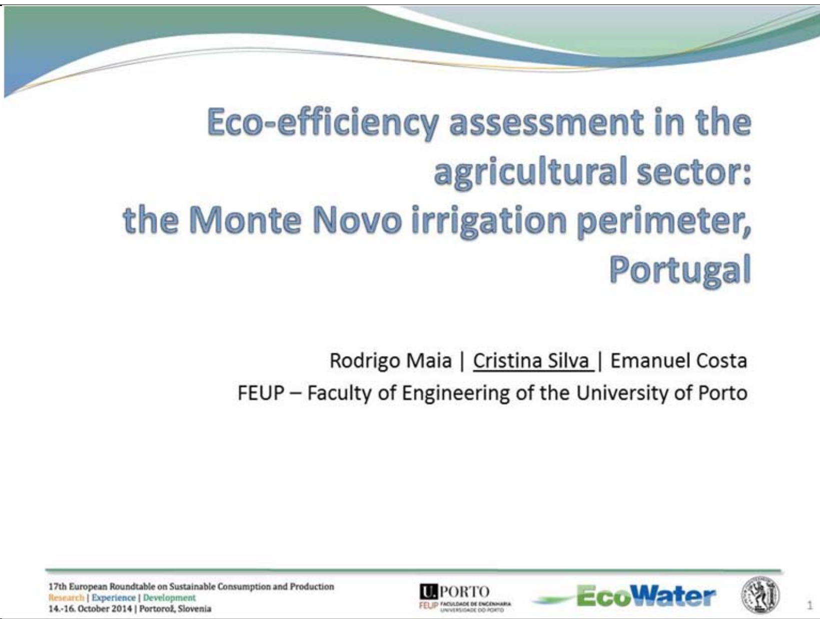
2.5.2 Presentation

(1)	

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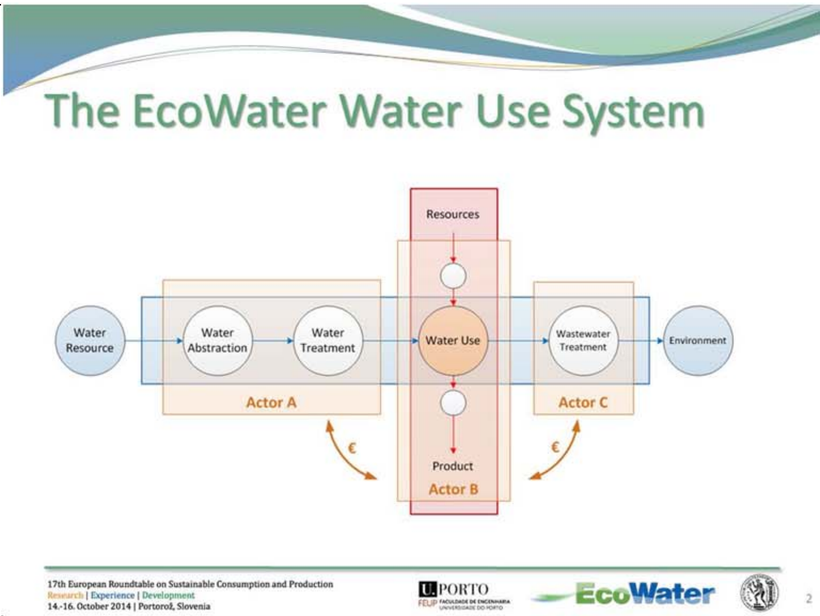
The EcoWater Water Use System
Resources
Water Resource
Water Abstraction
Water Treatment
Water Use
Wastewater Treatment
Environment
Actor A
Actor C
€
€
Product
Actor B
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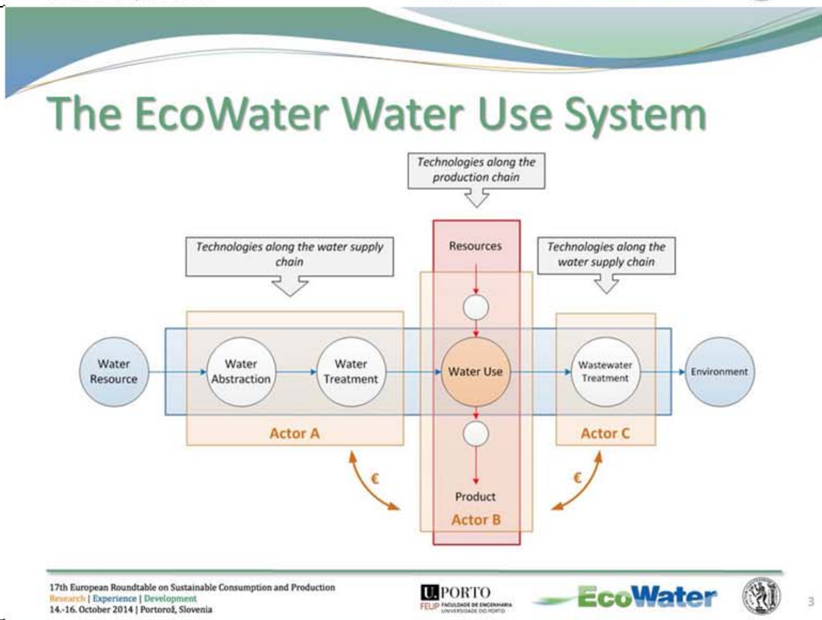
The EcoWater Water Use System
Technologies along the production chain
Technologies along the water supply chain
Resources
Technologies along the water supply chain
Water Resource
Water Abstraction
Water Treatment
Water Use
Wastewater Treatment
Environment
Actor A
Actor C
€
€
Product
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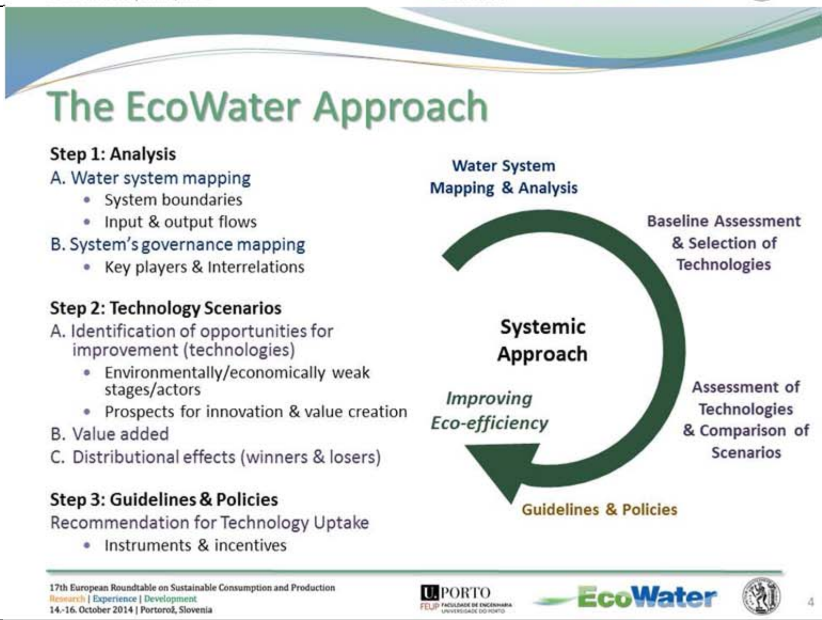
The EcoWater Approach
Step 1: Analysis
A. Water system mapping
• System boundaries
• Input & output flows
B. System's governance mapping
• Key players & Interrelations
Step 2: Technology Scenarios
A. Identification of opportunities for improvement (technologies)
• Environmentally/economically weak stages/actors
• Prospects for innovation & value creation
B. Value added
C. Distributional effects (winners & losers)
Step 3: Guidelines & Policies
Recommendation for Technology Uptake
• Instruments & incentives
Water System Mapping & Analysis
Baseline Assessment & Selection of Technologies
Systemic Approach
Improving Eco-efficiency
Assessment of Technologies & Comparison of Scenarios
Guidelines & Policies
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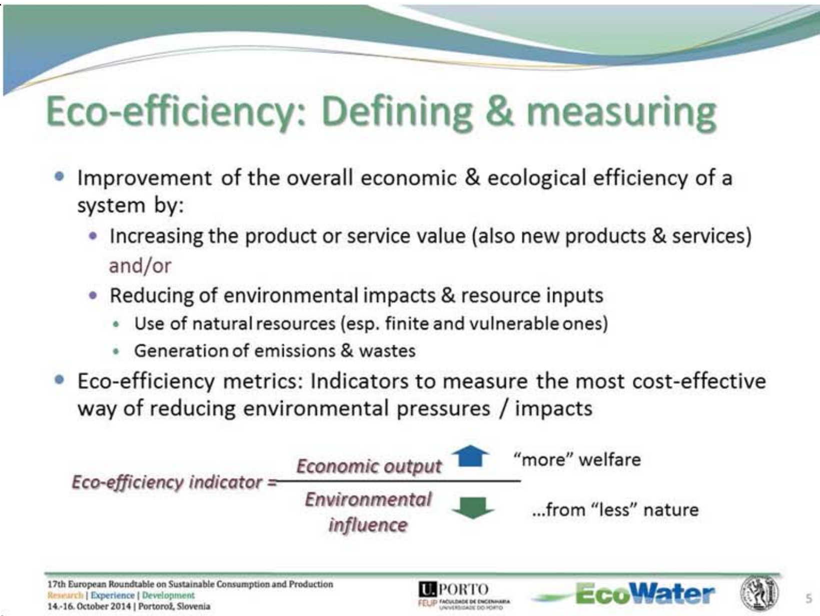
<tr><td>(5)</td><td>
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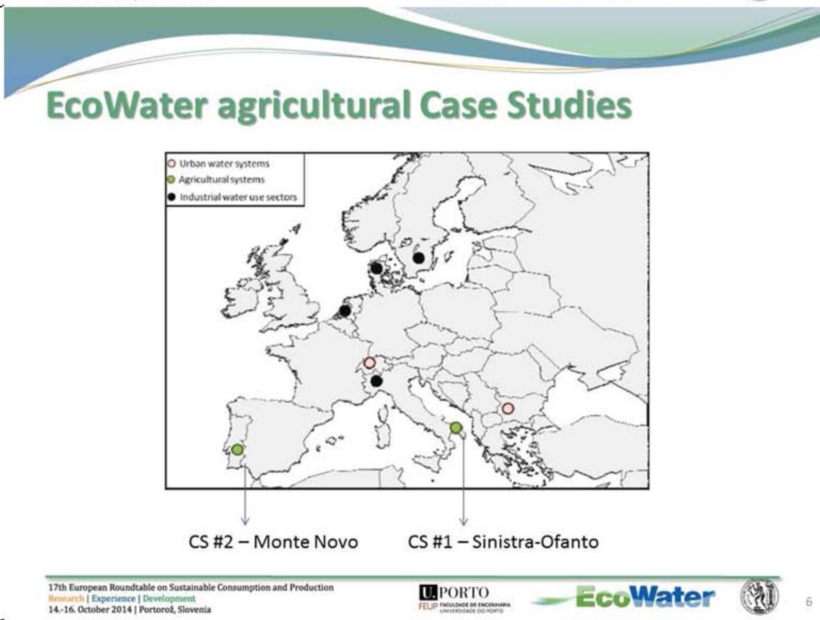
<tr><td>(6)</td><td>
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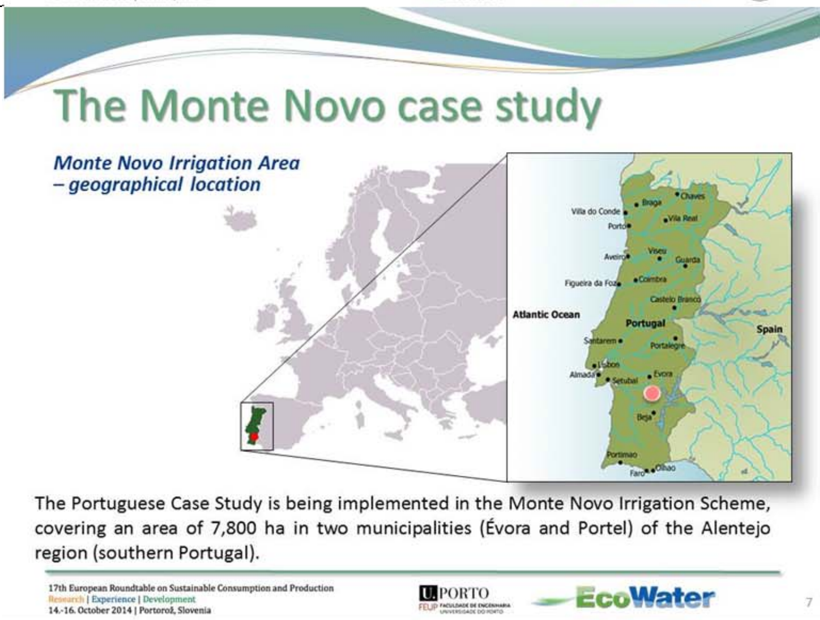
<tr><td>(7)</td><td>
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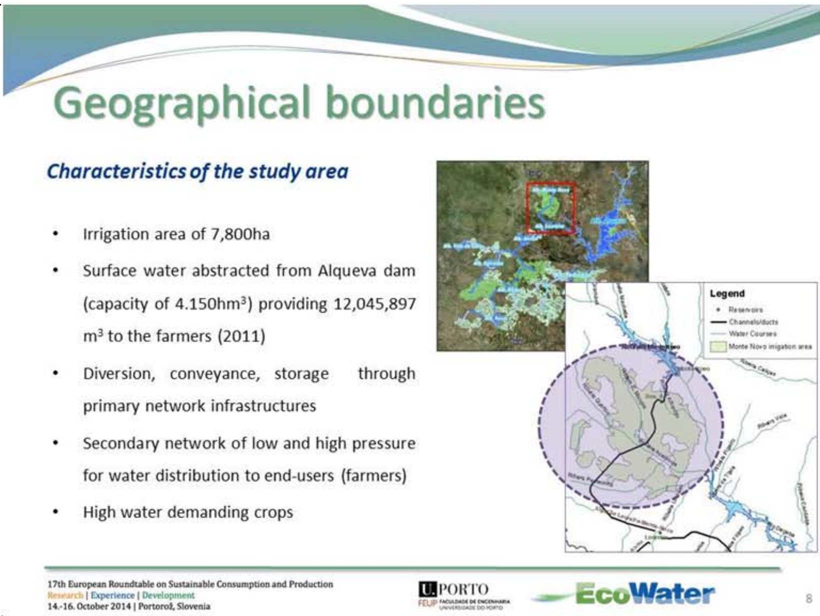
Geographical boundaries
Characteristics of the study area
Irrigation area of 7,800ha
Surface water abstracted from Alqueva dam (capacity of 4.150hm³) providing 12,045,897 m³ to the farmers (2011)
Diversion, conveyance, storage through primary network infrastructures
Secondary network of low and high pressure for water distribution to end-users (farmers)
High water demanding crops
Legend
Reservoirs
Channels/ducts
Water Courses
Monte Novo irrigation area
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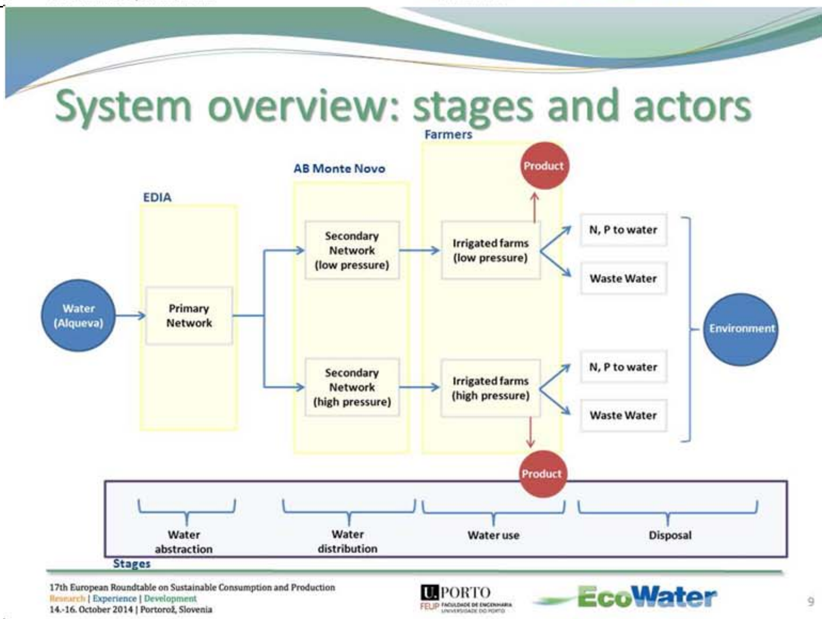
System overview: stages and actors
Farmers
AB Monte Novo
EDIA
Product
Water (Alqueva)
Primary Network
Secondary Network (low pressure)
Secondary Network (high pressure)
Irrigated farms (low pressure)
Irrigated farms (high pressure)
N, P to water
Waste Water
N, P to water
Waste Water
Environment
Product
Water abstraction
Water distribution
Water use
Disposal
Stages
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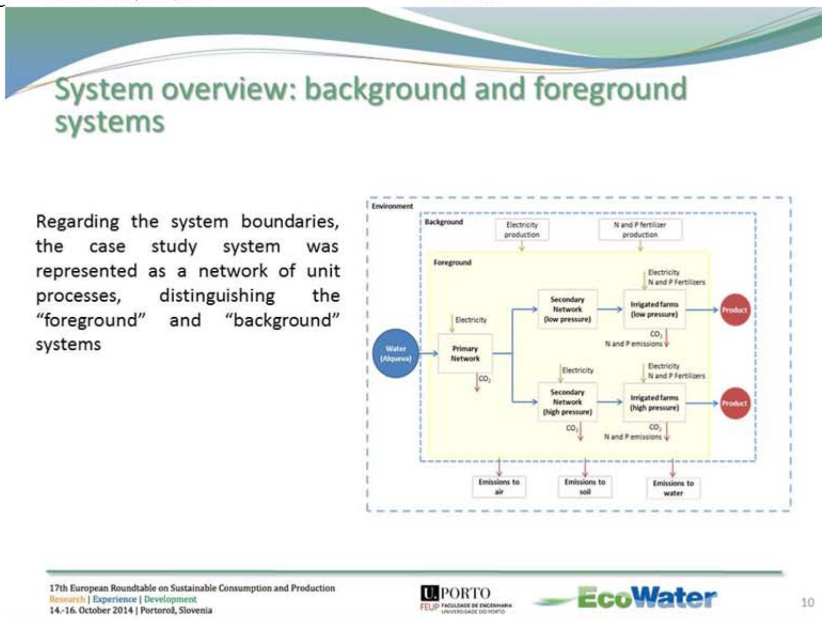
System overview: background and foreground systems
Regarding the system boundaries, the case study system was represented as a network of unit processes, distinguishing the "foreground" and "background" systems
Environment
Background
Electricity production
N and P fertilizer production
Foreground
Electricity
N and P Fertilizers
Water (Alqueva)
Primary Network
Electricity
CO₂
Secondary Network (low pressure)
Irrigated farms (low pressure)
CO₂
N and P emissions
Product
Electricity
Secondary Network (high pressure)
CO₂
Electricity
N and P Fertilizers
Irrigated farms (high pressure)
CO₂
N and P emissions
Product
Emissions to air
Emissions to soil
Emissions to water
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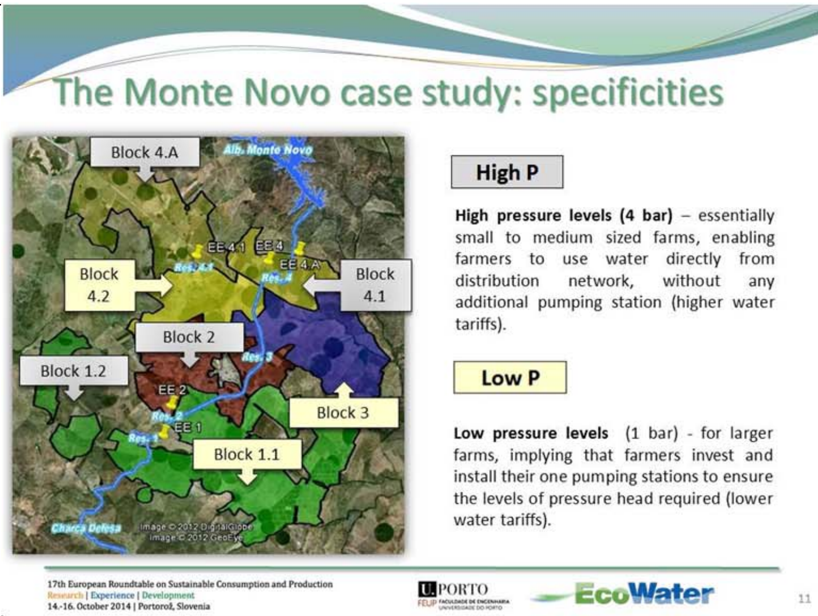

The Monte Novo case study: specificities
Block 4.A
Alb. Monte Novo
Block 4.2
Block 4.1
Block 2
Block 1.2
Block 3
Block 1.1
EE 4.1
EE 4
EE 4 A
EE 2
EE 1
Res. 4.1
Res. 4
Res. 3
Res. 2
Res. 1
Charca Defesa
Image © 2012 DigitalGlobe
Image © 2012 GeoEye
High P
High pressure levels (4 bar) – essentially small to medium sized farms, enabling farmers to use water directly from distribution network, without any additional pumping station (higher water tariffs).
Low P
Low pressure levels (1 bar) - for larger farms, implying that farmers invest and install their one pumping stations to ensure the levels of pressure head required (lower water tariffs).
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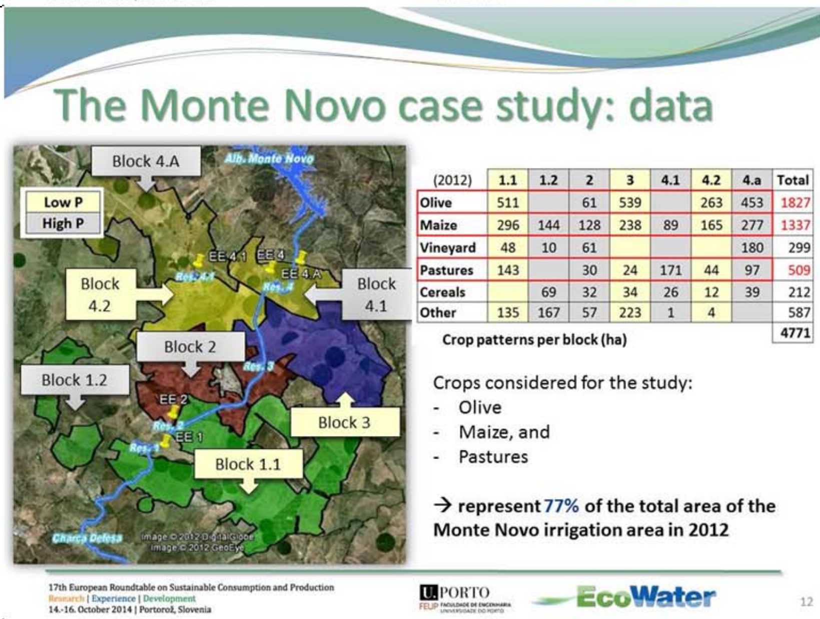

The Monte Novo case study: data
Block 4.A
Alb. Monte Novo
Low P
High P
Block 4.2
Block 4.1
Block 2
Block 1.2
Block 3
Block 1.1
Charca Defesa
Image © 2012 DigitalGlobe
Image © 2012 GeoEye

(2012)	1.1	1.2	2	3	4.1	4.2	4.a	Total
Olive	511		61	539		263	453	1827
Maize	296	144	128	238	89	165	277	1337
Vineyard	48	10	61				180	299
Pastures	143		30	24	171	44	97	509
Cereals		69	32	34	26	12	39	212
Other	135	167	57	223	1	4		587
								4771

Crop patterns per block (ha)
Crops considered for the study:
- Olive
- Maize, and
- Pastures
→ represent 77% of the total area of the Monte Novo irrigation area in 2012
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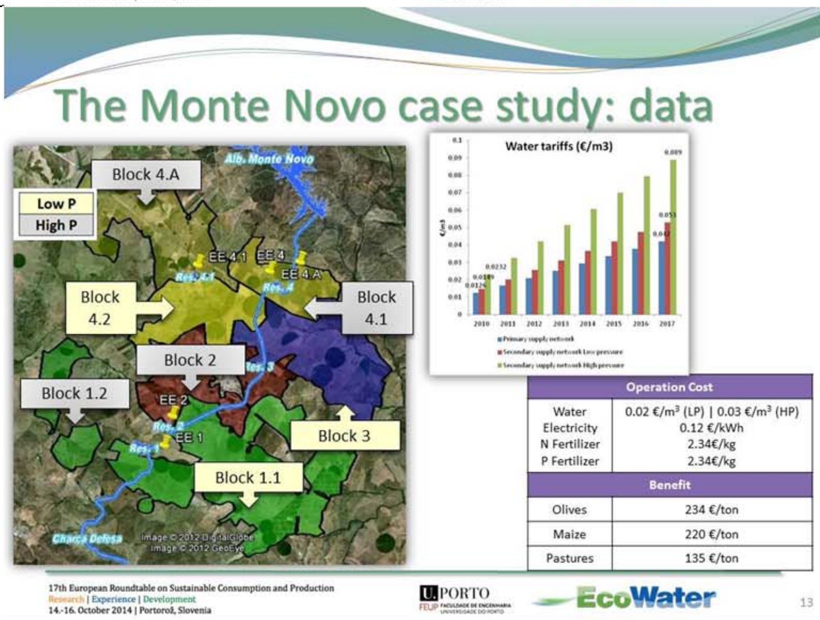

The Monte Novo case study: data
Block 4.A
Alb. Monte Novo
Low P
High P
Block 4.2
Block 4.1
Block 2
Block 1.2
Block 3
Block 1.1
Charca Defesa
Water tariffs (€/m3)
2010 2011 2012 2013 2014 2015 2016 2017

Operation Cost	
Water Electricity N Fertilizer P Fertilizer	0.02 €/m³ (LP) | 0.03 €/m³ (HP) 0.12 €/kWh 2.34€/kg 2.34€/kg
Benefit	
Olives	234 €/ton
Maize	220 €/ton
Pastures	135 €/ton

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Methodology for eco-efficiency assessment

Baseline scenario

Economic assessment

Actor	Annual O&M Cost (€/yr)	Annual Gross Income (€/yr)	Revenues from Water Services (€/yr)	Net Cash Flow (€/yr)
EDIA	684,709.65	0.00	395,196.55	-289,513.10
AB Monte Novo	265,224.07	0.00	278,416.37	13,192.29
Farmers	6,446,884.00	9,395,490.00	-673,612.92	2,274,993.08
Total	7,396,817.73	9,395,490.00	0.00	1,998,672.27

(15)

Methodology for eco-efficiency assessment

Baseline scenario

Environmental performance

Indicator (Unit)	Total Value	Foreground Value	Background Value
Climate Change (tCO2eq)	10,761.65	0	10,761.65)
Fossil Fuels Depletion (MJ)	124,668,758.19	0	124,668,758.19
Freshwater Resource Depletion (m3)	3,189,641.23	3,189,641.23	0
Eutrophication (kgPO4eq)	129,621.29	105,703.29	23,918.00
Human Toxicity (kg1,4-DBeq)	1,186,343.42	0	1,186,343.42
Acidification (kgSO2eq)	91,680.89	0	91,680.89
Aquatic Ecotoxicity (kg1,4-DBeq)	182,956.92	0	182,956.92
Terrestrial Ecotoxicity (kg1,4-DBeq)	18,786.18	0	18,786.18
Respiratory Inorganics (kgPM10,eq)	13,961.50	0	13,961.50
Photochemical Ozone Formation (kgC2H4,eq)	3,854.12	0	3,854.12
Mineral Depletion (kgFe-eq)	2,165.45	0	2,165.45

(16)

Results - Baseline scenario (2012)

Eco-efficiency Indicator	Value
Climate Change (€/tCO2eq)	185.72
Fossil fuels depletion (€/MJ)	0.02
Freshwater resource depletion (€/m³)	0.63
Eutrophication (€/kgPO4-3,eq)	15.42
Human toxicity (€/kg1,4-Dbeq)	1.68
Acidification (€/kgSO2-,eq)	21.80
Aquatic Ecotoxicity (€/kg1,4-Dbeq)	10.92
Terrestrial Ecotoxicity (€/kg1,4-Dbeq)	106.39
Respiratory inorganics (€/kgPM10,eq)	143.16
Ozone formation (€/kgC2H4,eq)	518.58
Minerals depletion (€/kg Fe-eq)	922.98

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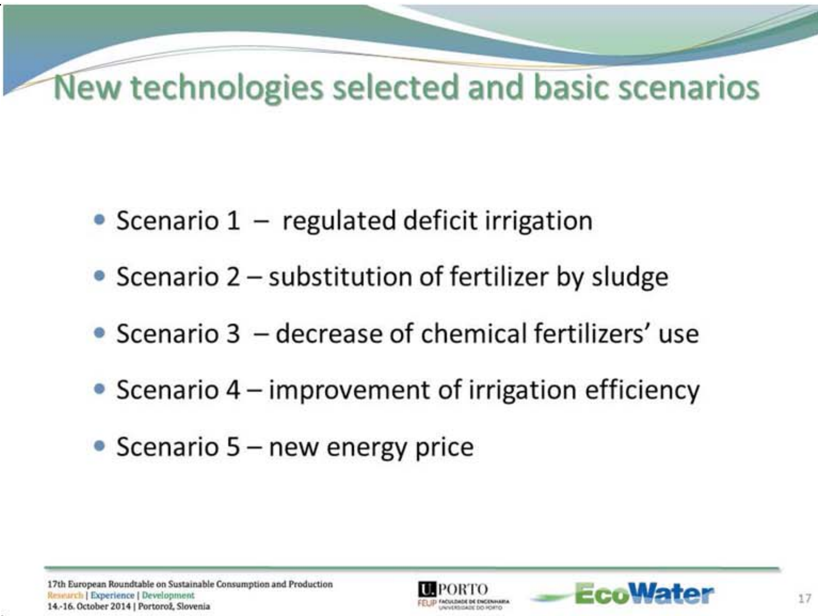
New technologies selected and basic scenarios
• Scenario 1 – regulated deficit irrigation
• Scenario 2 – substitution of fertilizer by sludge
• Scenario 3 – decrease of chemical fertilizers' use
• Scenario 4 – improvement of irrigation efficiency
• Scenario 5 – new energy price
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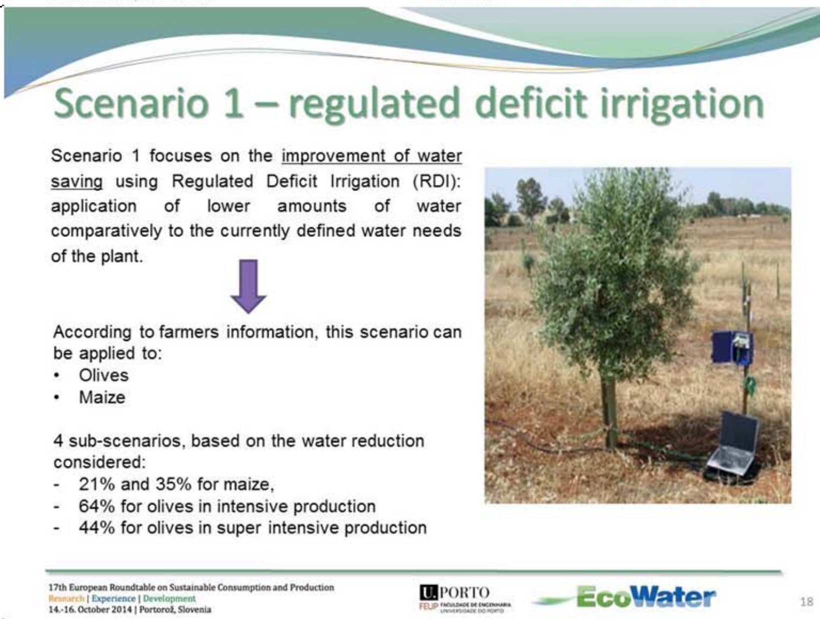
Scenario 1 – regulated deficit irrigation
Scenario 1 focuses on the improvement of water saving using Regulated Deficit Irrigation (RDI): application of lower amounts of water comparatively to the currently defined water needs of the plant.
According to farmers information, this scenario can be applied to:
• Olives
• Maize
4 sub-scenarios, based on the water reduction considered:
- 21% and 35% for maize,
- 64% for olives in intensive production
- 44% for olives in super intensive production
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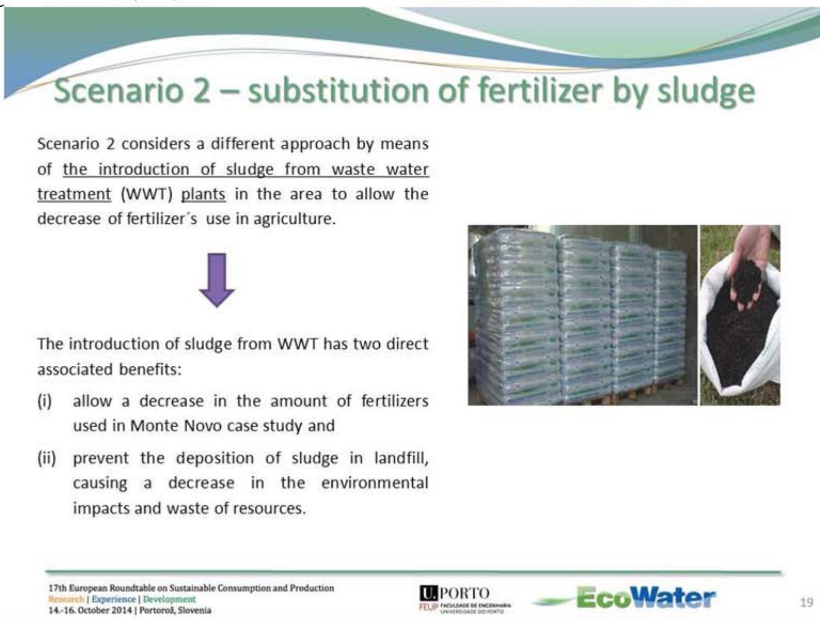
Scenario 2 – substitution of fertilizer by sludge
Scenario 2 considers a different approach by means of the introduction of sludge from waste water treatment (WWT) plants in the area to allow the decrease of fertilizer´s use in agriculture.
The introduction of sludge from WWT has two direct associated benefits:
(i) allow a decrease in the amount of fertilizers used in Monte Novo case study and
(ii) prevent the deposition of sludge in landfill, causing a decrease in the environmental impacts and waste of resources.
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Scenario 3 – decrease of chemical fertilizer's use

Scenario 3 analyses the decrease in chemical fertilizers´ use through the introduction of organic compounds appropriate for biological agriculture.

The use of this type of fertilization can simultaneously provide nutrients and improve soil quality

Main advantage: the change from traditional agriculture to organic agriculture allows a 20% increase in the price to be paid to the farmer

However, as **main disadvantage**, the use of organic fertilizer is usually related with an increase in costs.

Crop	Quantity (kg/ha)	Cost (€/ha)
Maize	700	420
Olives	600	360
Pastures	467	280

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Scenario 4 – improvement of irrigation efficiency

Scenario 4 focuses on the improvement of the irrigation efficiency through the adoption of subsurface drip irrigation (SDI) instead of drip irrigation, for **maize** and **olives**.

Operational conditions:

↓ Water consumtion - 25%;
↓ Energy consumption - 25%;

Overall on-farm efficiency:
Sprinkler (80%) ⇒ SDI (95%)
Drip irrigation (90%) ⇒ SDI (95%)

Economic considerations: The investment cost associated with a subsurface drip irrigation system is considered to be around 5000 €/ha, and the corresponding operation and maintenance costs around 600 €/ha/year (12% of the investment cost), for a 15 years' lifetime

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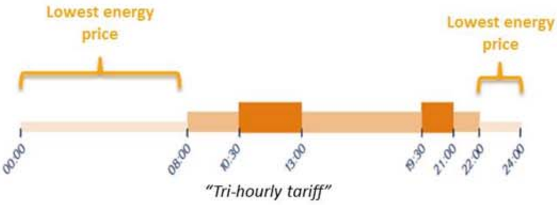
Scenario 5 – new energy price

Scenario 5 considers an improvement in irrigation costs by means of a new scheduling of irrigation, during periods of lower energy price. Energy costs associated with agriculture in the Monte Novo irrigation perimeter are mainly due to the use of water pumps to supply water to the crops in the low pressure blocks.

→ After several contacts made with farmers associations producing olives and/or maize, no disadvantages associated with the irrigation during the specific low cost energy period were identified.

Applied to:

- Maize
- Olives



Economic data: decrease in the energy price from 0.115€/kWh to 0.0831€/kWh (corresponding to a 28% reduction).

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New technologies selected and basic scenarios

Promoting ressource efficiency

- Scenario 1 - regulated deficit irrigation
- Scenario 4 – improvement of irrigation efficiency

Focusing on pollution prevention

- Scenario 2 – substitution of fertilizer by sludge
- Scenario 3 - decrease of chemical fertilizers' use

- Scenario 5 – new energy price

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Results – scenarios promoting ressource efficiency

Eco-efficiency Indicator	Baseline Scen.	Maize RDI (21%)	Maize RDI (35%)	Maize SDI	Olives RDI (64%)	Olives RDI (44%)	Olives SDI
Climate Change (€/tCO2eq)	185.7	210.5	225.0	110.8	199.8	192.0	153.0
Fossil fuels depletion (€/MJ)	0.02	0.02	0.02	0.01	0.02	0.02	0.01
Freshwater resource depletion (€/m^3)	0.63	0.75	0.82	0.39	0.69	0.66	0.51
Eutrophication (€/kgPO4-3,eq)	15.42	16.29	16.74	7.98	15.93	15.65	11.94
Human toxicity (€/kg1,4-Dbeq)	1.68	1.87	1.98	0.97	1.79	1.73	1.37
Acidification (€/kgSO2-,eq)	21.80	24.50	26.06	12.78	23.35	22.49	17.82
Aquatic Ecotoxicity (€/kg1,4-Dbeq)	10.92	11.70	12.12	5.81	11.38	11.13	8.56
Terrestrial Ecotoxicity (€/kg1,4-Dbeq)	106.4	121.5	130.4	64.49	115.0	110.1	88.19
Respiratory inorganics (€/kgPM10,eq)	143.2	161.2	171.7	84.27	153.5	147.7	117.2
Ozone formation (€/kgC2H4,eq)	518.6	582.8	619.74	303.9	555.3	534.9	424.0
Minerals depletion (€/kg Fe-eq)	923.0	1,055.4	1,133.9	561.1	998.2	956.1	766.0

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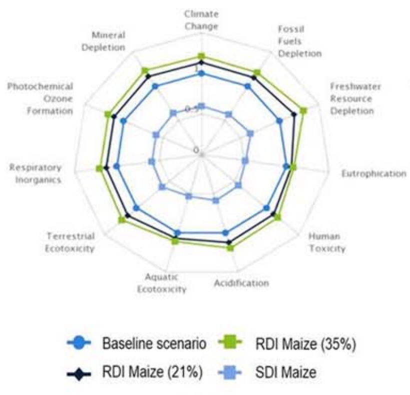
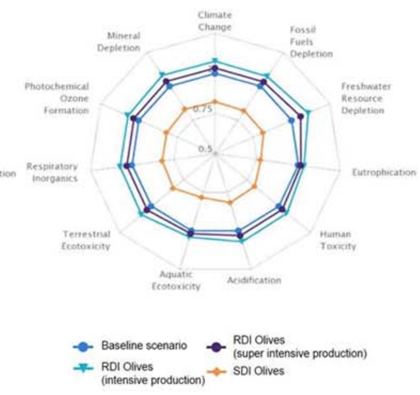
Results – scenarios promoting ressource efficiency



Maize



Olives

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Results – scenarios focusing on pollution prevention

Eco-efficiency Indicator	Baseline Scen.	Maize		
		Sludge (HP)	Sludge (LP)	Org. Fert.
Climate Change (€/tCO2eq)	185.7	193.15	193.15	304.4
Fossil fuels depletion (€/MJ)	0.02	0.02	0.02	0.03
Freshwater resource depletion (€/m³)	0.63	0.65	0.65	0.95
Eutrophication (€/kgPO4-3,eq)	15.42	17.07	17.06	83.00
Human toxicity (€/kg1,4-Dbeq)	1.68	1.78	1.78	3.38
Acidification (€/kgSO2-,eq)	21.80	22.83	22.83	38.72
Aquatic Ecotoxicity (€/kg1,4-Dbeq)	10.92	11.93	11.93	41.11
Terrestrial Ecotoxicity (€/kg1,4-Dbeq)	106.4	109.98	109.97	162.5
Respiratory inorganics (€/kgPM10,eq)	143.2	149.69	149.68	249.3
Ozone formation (€/kgC2H4,eq)	518.6	543.23	543.21	923.4
Minerals depletion (€/kg Fe-eq)	923.0	953.03	953.00	1,032.8

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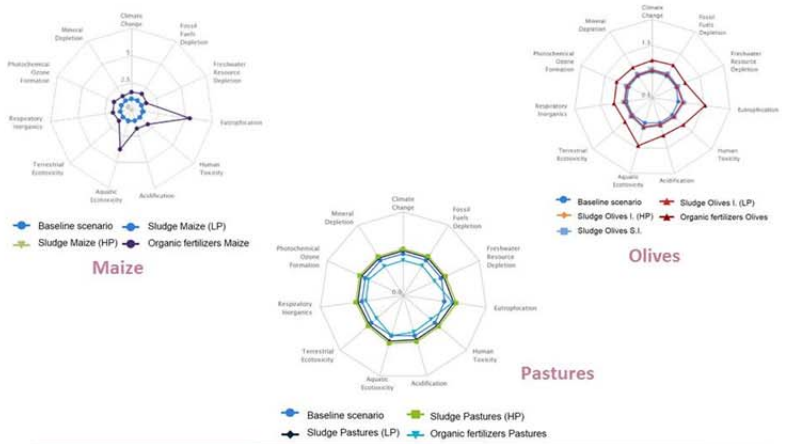
Results – scenarios focusing on pollution prevention



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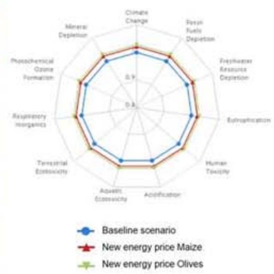
Results – new energy price

Eco-efficiency Indicator	Baseline	Maize (LP and HP)	Olives (LP and HP)
Climate Change (€/tCO2eq)	185.7	189.64	191.05
Fossil fuels depletion (€/MJ)	0.02	0.02	0.02
Freshwater resource depletion (€/m3)	0.63	0.64	0.64
Eutrophication (€/kgPO4-3,eq)	15.42	15.75	15.86
Human toxicity (€/kg1,4-Dbeq)	1.68	1.72	1.73
Acidification (€/kgSO2-,eq)	21.80	22.26	22.43
Aquatic Ecotoxicity (€/kg1,4-Dbeq)	10.92	11.16	11.24
Terrestrial Ecotoxicity (€/kg1,4-Dbeq)	106.4	108.64	109.44
Respiratory inorganics (€/kgPM10,eq)	143.2	146.18	147.27
Ozone formation (€/kgC2H4,eq)	518.6	529.53	533.47
Minerals depletion (€/kg Fe-eq)	923.0	942.48	949.48



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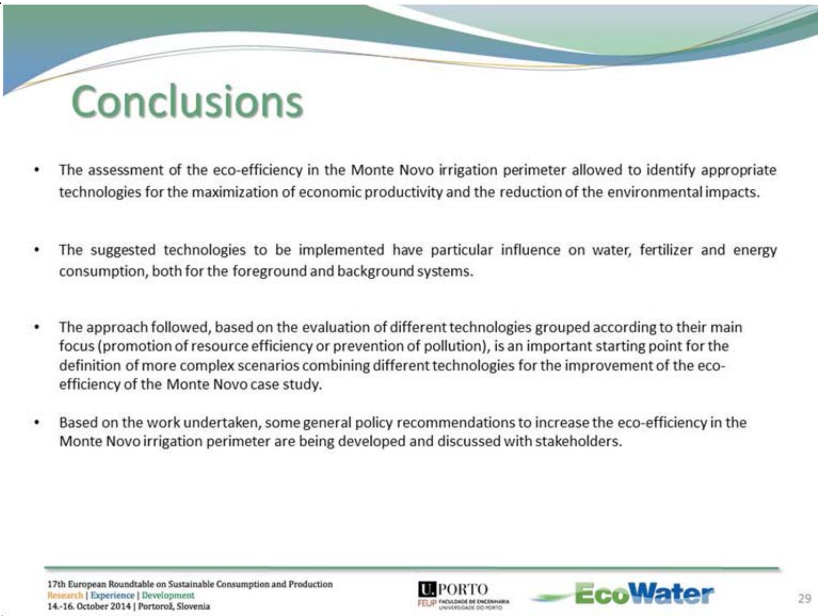
Conclusions
• The assessment of the eco-efficiency in the Monte Novo irrigation perimeter allowed to identify appropriate technologies for the maximization of economic productivity and the reduction of the environmental impacts.
• The suggested technologies to be implemented have particular influence on water, fertilizer and energy consumption, both for the foreground and background systems.
• The approach followed, based on the evaluation of different technologies grouped according to their main focus (promotion of resource efficiency or prevention of pollution), is an important starting point for the definition of more complex scenarios combining different technologies for the improvement of the eco-efficiency of the Monte Novo case study.
• Based on the work undertaken, some general policy recommendations to increase the eco-efficiency in the Monte Novo irrigation perimeter are being developed and discussed with stakeholders.
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2.6 Complexity, assumptions and solutions for eco-efficiency assessment of urban water systems

Peyo STANCHEV[1], Galina DIMOVA[1], Irina RIBAROVA[1]

[1] Faculty of Hydraulic Engineering, Water Supply, Sewerage, Water and Wastewater Treatment, University of Architecture, Civil Engineering and Geodesy, Bulgaria

2.6.1 Abstract

ISO Standard 14045 on eco-efficiency, issued a year ago, provides guidelines for assessment of two of the pillars of sustainability: the economic and the environmental performance as well as their relation. The standard defines only the general framework and requires research approach to be applied for each particular case. This paper presents the approach, developed in EU funded research project EcoWater and its application for an urban water system. It discusses how the difficulties were addressed, the assumptions, which had to be made and the solutions, which were suggested.

The urban water systems are engineering systems, developed to serve one of the most vital social needs – provision of drinking water. Their design, construction, operation and maintenance comprise a number of economic activities which besides their primary social function turns them also into product systems. These characteristics make their sustainability evaluation very complex, since both environmental and economic approaches should be applied in a coherent way to an engineering system that serves different users and has various interconnected social, economic and environmental impacts. At one hand are the domestic water users, who often are socially and culturally quite heterogeneous and their behaviour is difficult to be modelled; on the other hand are the non-domestic users who are even more heterogeneous and the economic value from their water use is often either hidden within the lump sum of the product or is hard to be calculated due to lack of specific measurements. Furthermore the urban water system in general consists of two subsystems: the water supply and the sewerage system, which have quite different functions leading to difficulties in definition of the product and the functional unit of the system. Although lack of measurements is a common problem for most studies, it should be mentioned also here, because urban water systems lack of essential data as direct emissions from the sewerage system to the environment, water demand in households, domestic and industrial wastewater quality, etc.

The Sofia urban water system in Bulgaria, serving about 1,5 million citizens, was selected for testing of the approach. In this system, freshwater is abstracted from two reservoirs, followed by purification in three water treatment plants and transportation to the customers by gravity distribution network. The generated wastewater is collected by gravity and is treated in

conventional waste water treatment plant prior its discharge into Iskar river. The baseline eco-efficiency assessment revealed that: 1) the stage with the weakest environmental performance is the domestic water use, followed by the wastewater treatment stage; 2) the energy is the material flow with the highest impact on the eco-efficiency performance of the system.

These results assisted in identifying measures for eco-efficiency improvement. The paper presents eco-efficiency of the system before and after implementation of the measures.

Keywords
Eco-efficiency, ISO 14045, Indicators, Urban water systems, LCIA

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2.6.2 Presentation

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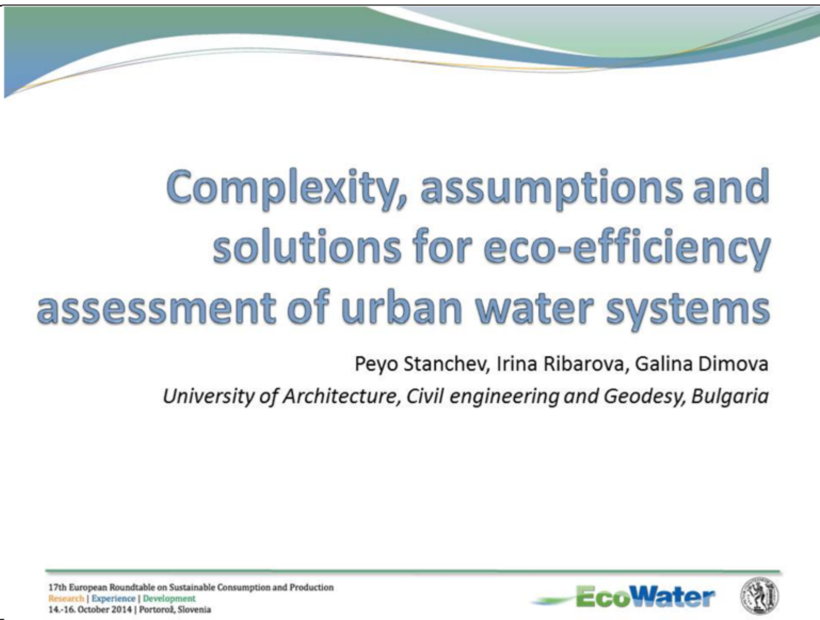

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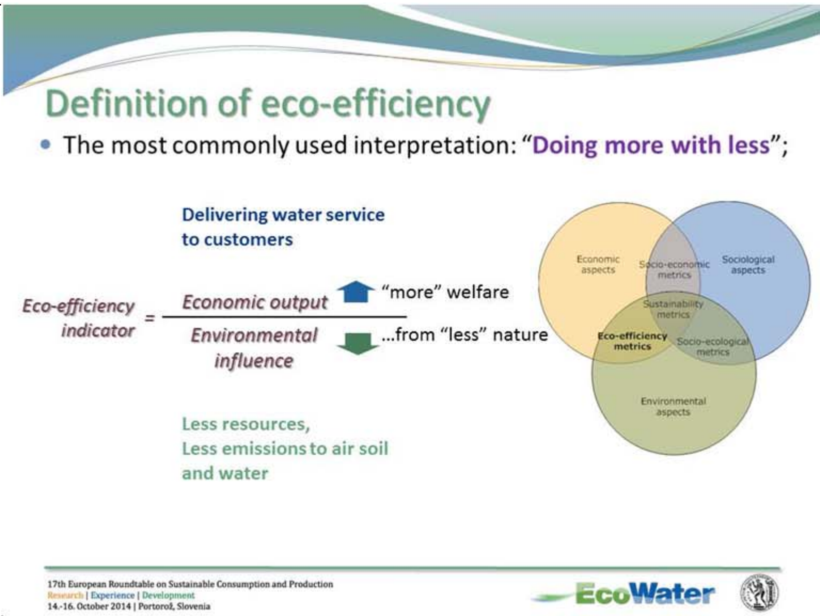

Definition of eco-efficiency
The most commonly used interpretation: "Doing more with less";
Delivering water service to customers
Eco-efficiency indicator =
Economic output
"more" welfare
Environmental influence
...from "less" nature
Less resources, Less emissions to air soil and water
Economic aspects
Socio-economic metrics
Sociological aspects
Sustainability metrics
Eco-efficiency metrics
Socio-ecological metrics
Environmental aspects
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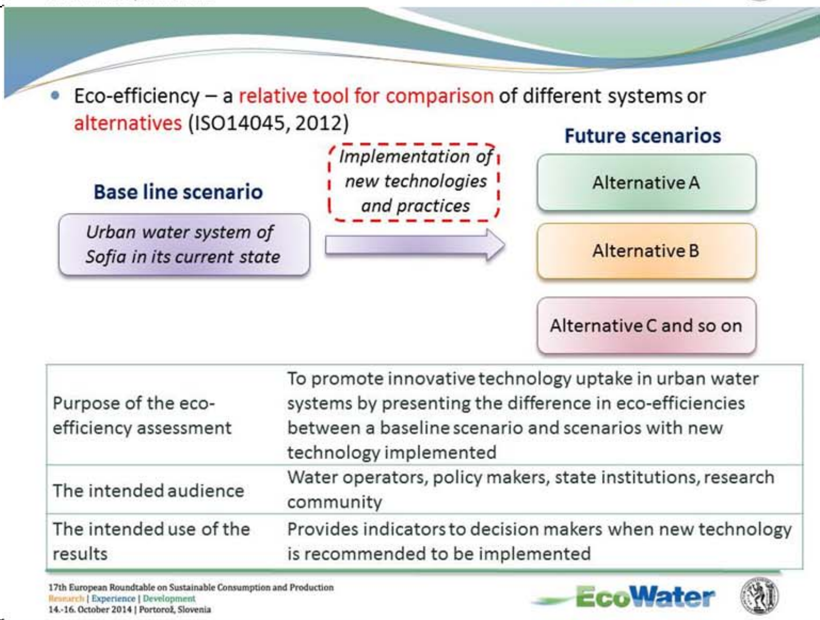

Eco-efficiency – a relative tool for comparison of different systems or alternatives (ISO14045, 2012)
Future scenarios
Implementation of new technologies and practices
Base line scenario
Urban water system of Sofia in its current state
Alternative A
Alternative B
Alternative C and so on
Purpose of the eco-efficiency assessment
To promote innovative technology uptake in urban water systems by presenting the difference in eco-efficiencies between a baseline scenario and scenarios with new technology implemented
The intended audience
Water operators, policy makers, state institutions, research community
The intended use of the results
Provides indicators to decision makers when new technology is recommended to be implemented
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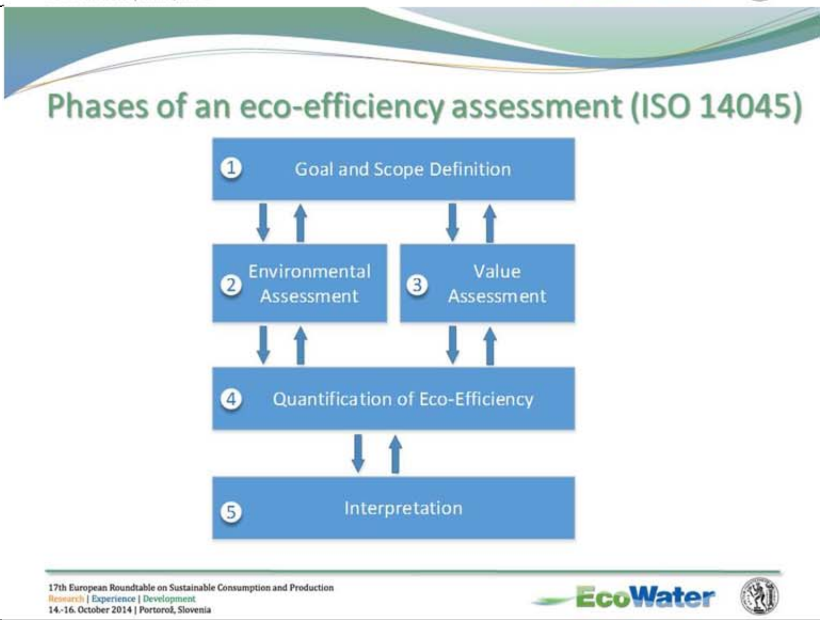

Phases of an eco-efficiency assessment (ISO 14045)
1 Goal and Scope Definition
2 Environmental Assessment
3 Value Assessment
4 Quantification of Eco-Efficiency
5 Interpretation
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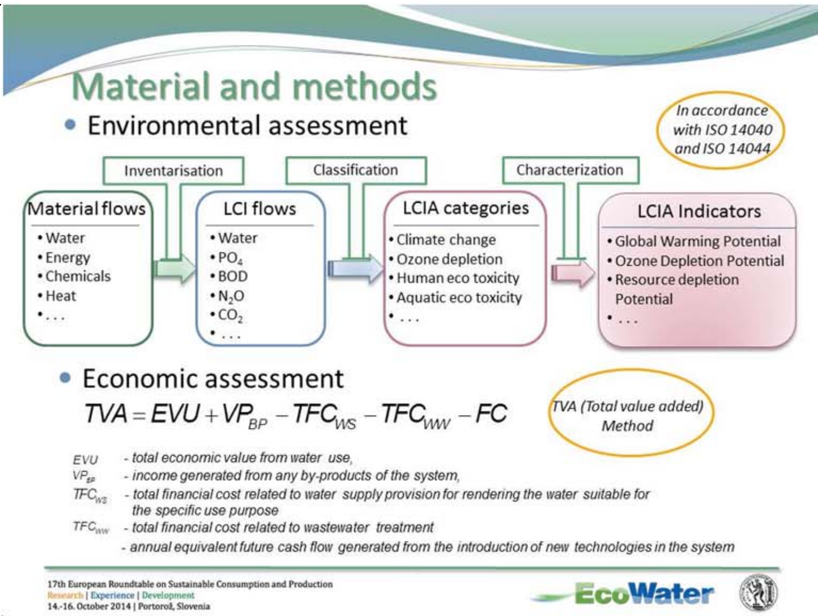

Material and methods
Environmental assessment
In accordance with ISO 14040 and ISO 14044
Inventarisation
Classification
Characterization
Material flows
Water
Energy
Chemicals
Heat
...
LCI flows
Water
PO_4
BOD
N_2O
CO_2
...
LCIA categories
Climate change
Ozone depletion
Human eco toxicity
Aquatic eco toxicity
...
LCIA Indicators
Global Warming Potential
Ozone Depletion Potential
Resource depletion Potential
...
Economic assessment
$TVA = EVU + VP_{BP} - TFC_{WS} - TFC_{WW} - FC$
TVA (Total value added) Method
EVU - total economic value from water use,
VP_{BP} - income generated from any by-products of the system,
TFC_{WS} - total financial cost related to water supply provision for rendering the water suitable for the specific use purpose
TFC_{WW} - total financial cost related to wastewater treatment
- annual equivalent future cash flow generated from the introduction of new technologies in the system
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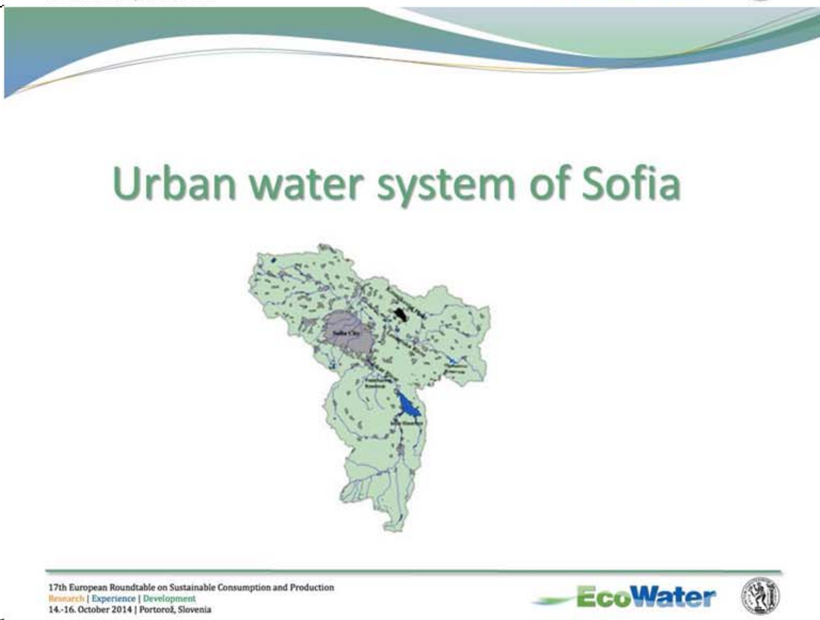

Urban water system of Sofia
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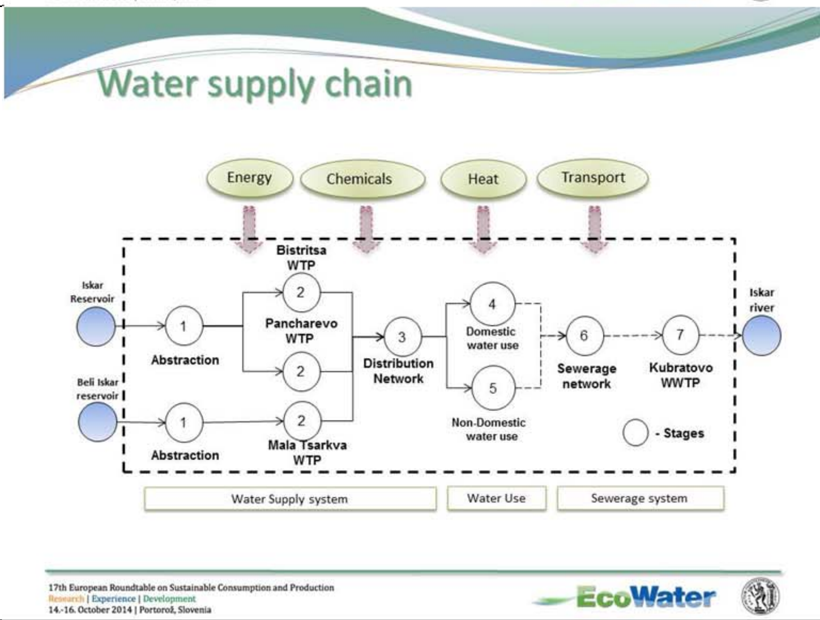

Water supply chain
Energy
Chemicals
Heat
Transport
Iskar Reservoir
Beli Iskar reservoir
1
Abstraction
1
Abstraction
Bistritsa WTP
2
Pancharevo WTP
2
2
Mala Tsarkva WTP
3
Distribution Network
4
Domestic water use
5
Non-Domestic water use
6
Sewerage network
7
Kubratovo WWTP
Iskar river
- Stages
Water Supply system
Water Use
Sewerage system
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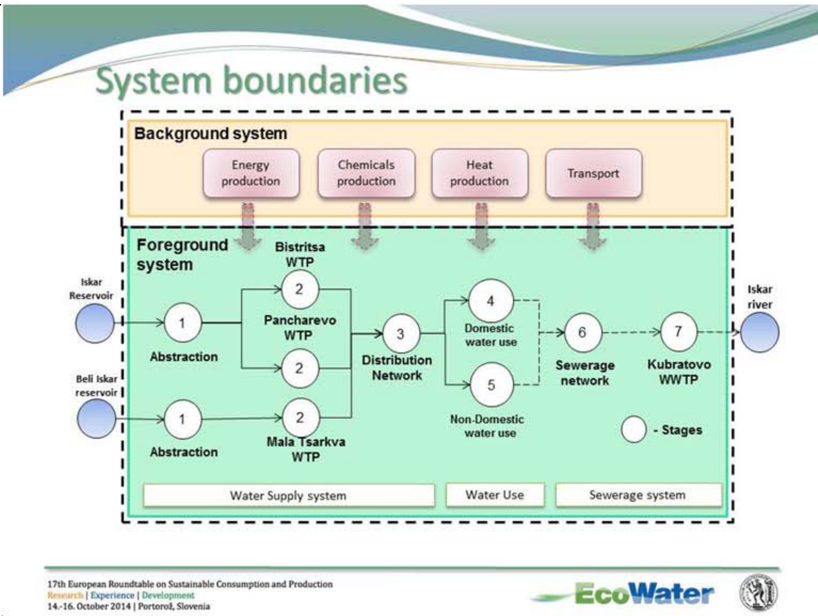
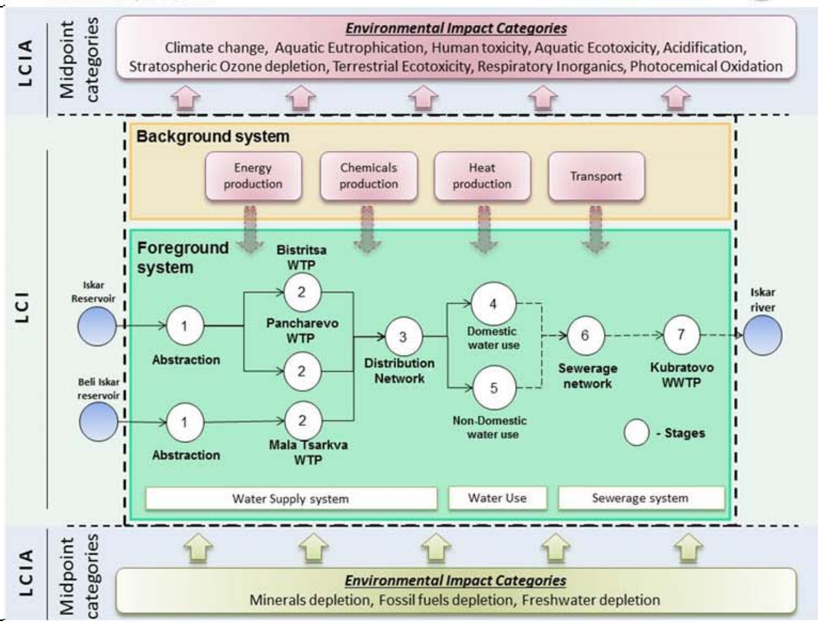
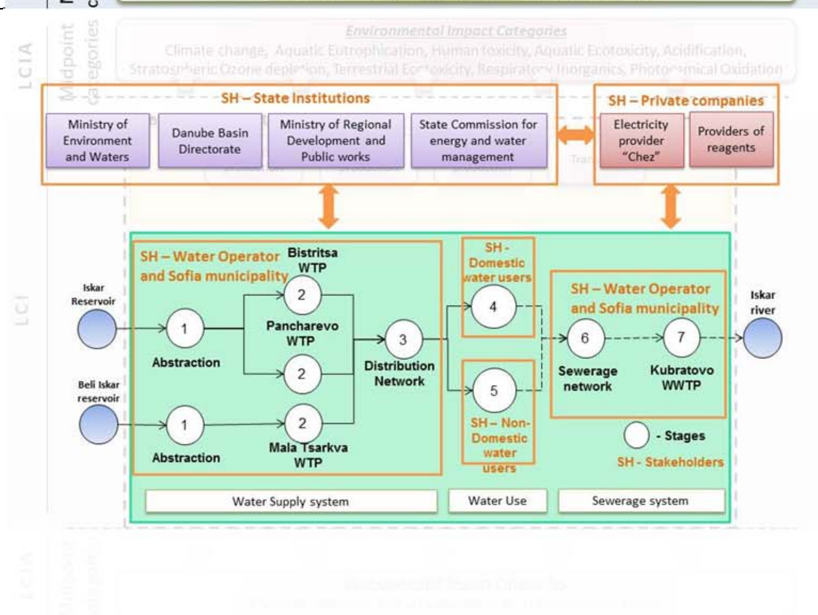
(8)	System boundaries Background system Energy production Chemicals production Heat production Transport Foreground system Iskar Reservoir Beli Iskar reservoir Abstraction Bistritsa WTP Pancharevo WTP Mala Tsarkva WTP Distribution Network Domestic water use Non-Domestic water use Sewerage network Kubratovo WWTP Iskar river - Stages Water Supply system Water Use Sewerage system 17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater
(9)	LCIA Midpoint categories Environmental Impact Categories Climate change, Aquatic Eutrophication, Human toxicity, Aquatic Ecotoxicity, Acidification, Stratospheric Ozone depletion, Terrestrial Ecotoxicity, Respiratory Inorganics, Photocemical Oxidation LCI Background system Energy production Chemicals production Heat production Transport Foreground system Iskar Reservoir Beli Iskar reservoir Abstraction Bistritsa WTP Pancharevo WTP Mala Tsarkva WTP Distribution Network Domestic water use Non-Domestic water use Sewerage network Kubratovo WWTP Iskar river - Stages Water Supply system Water Use Sewerage system LCIA Midpoint categories Environmental Impact Categories Minerals depletion, Fossil fuels depletion, Freshwater depletion
(10)	SH – State Institutions Ministry of Environment and Waters Danube Basin Directorate Ministry of Regional Development and Public works State Commission for energy and water management SH – Private companies Electricity provider "Chez" Providers of reagents SH – Water Operator and Sofia municipality SH - Domestic water users SH – Non-Domestic water users SH – Water Operator and Sofia municipality Iskar Reservoir Beli Iskar reservoir Abstraction Bistritsa WTP Pancharevo WTP Mala Tsarkva WTP Distribution Network Sewerage network Kubratovo WWTP Iskar river - Stages SH - Stakeholders Water Supply system Water Use Sewerage system

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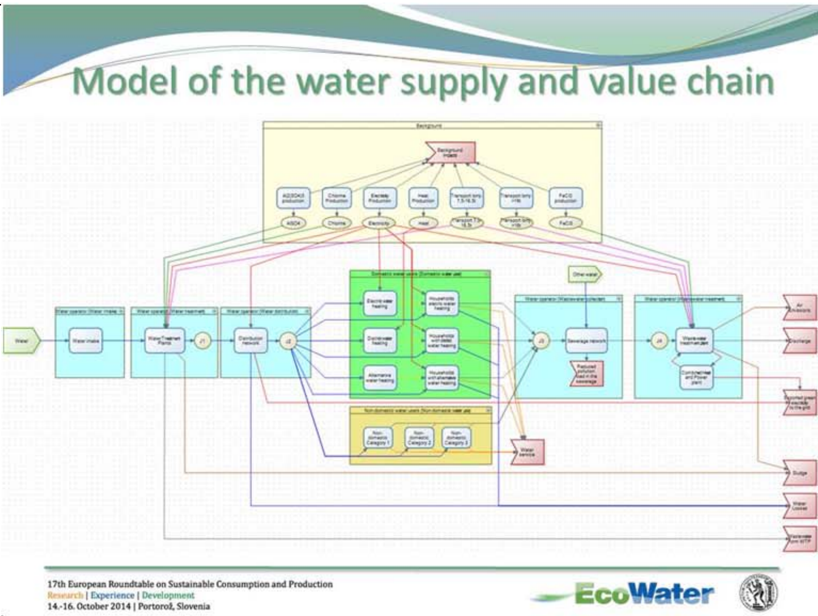

(12)

Challenges faced during the modeling of the system

Challenge	Solution
➢ Missing data about water demand in households.	Individual study was conducted in order to calculate the water demand per capita in household.
➢ Pollution load from domestic water users	Based on literature data BOD was assumed to be 60 g/ca.day
➢ The non-domestic users are presented by variety of industries with different flow and pollution patterns	The non-domestic users are classified in 3 categories depending on the quality of the discharged waste water and pollution load is calculated based on the quantity of discharged water in each category
➢ Estimation of rainwater, infiltration, exfiltration	Rainwater infiltration and exfiltration flows are considered outside of the scope of the study and are assumed to be constant in all scenarios
➢ Reduced pollution load in the sewerage network due to exfiltration, ➢ overflowing through CSOs, biodegradation in sewage network	These flows cannot be directly measured, thus they are estimated with the difference between the measured load on WWTP inlet and theoretically discharged load into the sewerage network
➢ Calculation of Economic Value from Water Use (EVU)	Willingness to pay was used as indirect method to assess the economic value to users from water use

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Results -
Baseline Eco-efficiency assessment

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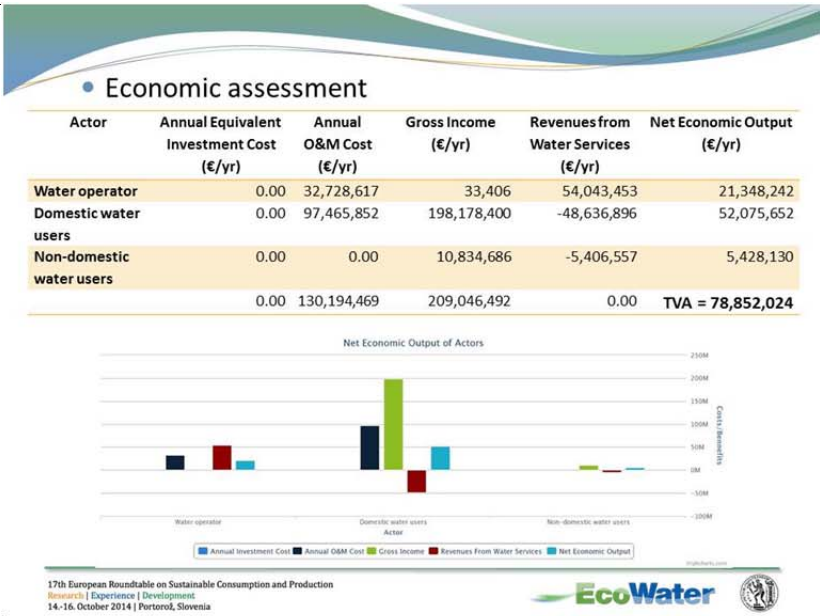

Actor	Annual Equivalent Investment Cost (€/yr)	Annual O&M Cost (€/yr)	Gross Income (€/yr)	Revenues from Water Services (€/yr)	Net Economic Output (€/yr)
Water operator	0.00	32,728,617	33,406	54,043,453	21,348,242
Domestic water users	0.00	97,465,852	198,178,400	-48,636,896	52,075,652
Non-domestic water users	0.00	0.00	10,834,686	-5,406,557	5,428,130
	0.00	130,194,469	209,046,492	0.00	TVA = 78,852,024

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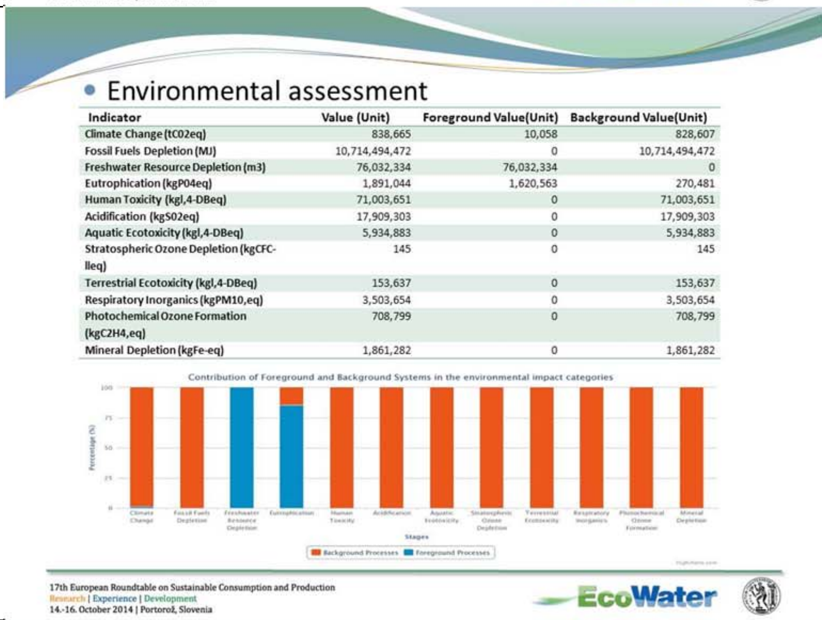

Indicator	Value (Unit)	Foreground Value(Unit)	Background Value(Unit)
Climate Change (tC02eq)	838,665	10,058	828,607
Fossil Fuels Depletion (MJ)	10,714,494,472	0	10,714,494,472
Freshwater Resource Depletion (m3)	76,032,334	76,032,334	0
Eutrophication (kgP04eq)	1,891,044	1,620,563	270,481
Human Toxicity (kgl,4-DBeq)	71,003,651	0	71,003,651
Acidification (kgS02eq)	17,909,303	0	17,909,303
Aquatic Ecotoxicity (kgl,4-DBeq)	5,934,883	0	5,934,883
Stratospheric Ozone Depletion (kgCFC-lleq)	145	0	145
Terrestrial Ecotoxicity (kgl,4-DBeq)	153,637	0	153,637
Respiratory Inorganics (kgPM10,eq)	3,503,654	0	3,503,654
Photochemical Ozone Formation (kgC2H4,eq)	708,799	0	708,799
Mineral Depletion (kgFe-eq)	1,861,282	0	1,861,282

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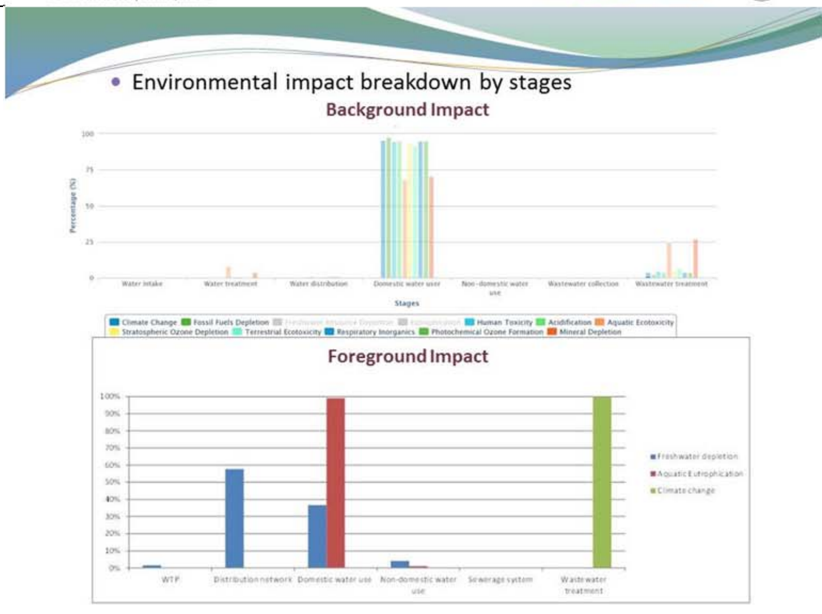

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Results -
Technology scenario assessment
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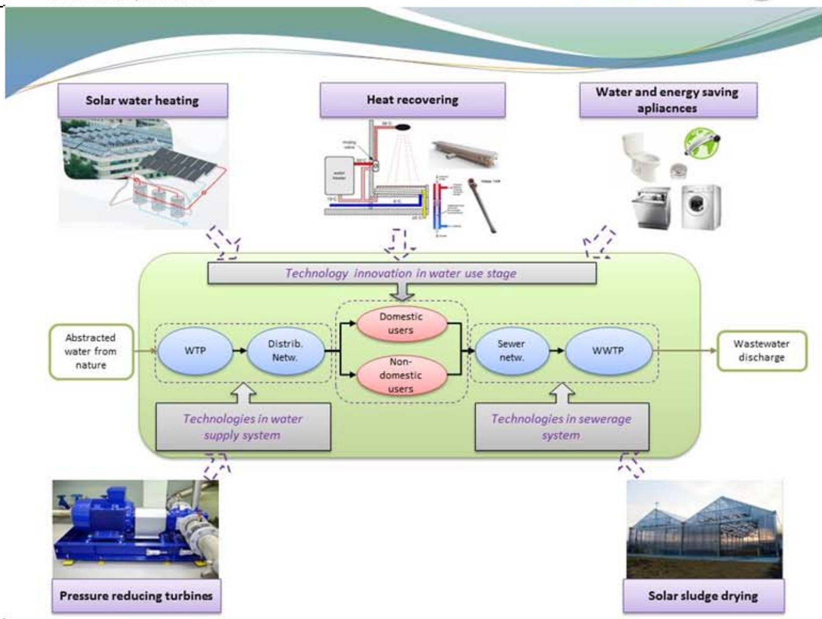

Solar water heating
Heat recovering
Water and energy saving apliacnces
Technology innovation in water use stage
Abstracted water from nature
WTP
Distrib. Netw.
Domestic users
Non-domestic users
Sewer netw.
WWTP
Wastewater discharge
Technologies in water supply system
Technologies in sewerage system
Pressure reducing turbines
Solar sludge drying

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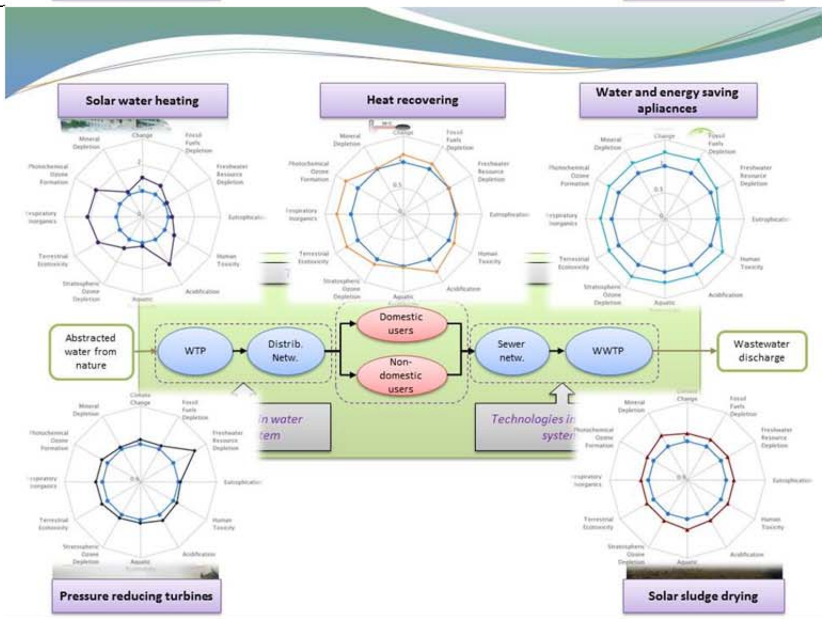

Solar water heating
Heat recovering
Water and energy saving apliacnces
Abstracted water from nature
WTP
Distrib. Netw.
Domestic users
Non-domestic users
Sewer netw.
WWTP
Wastewater discharge
Pressure reducing turbines
Solar sludge drying

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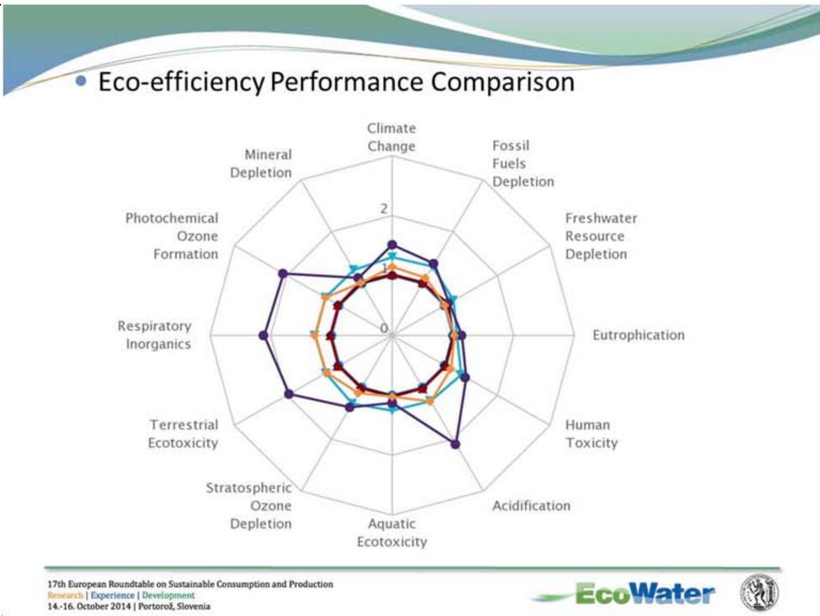

Eco-efficiency Performance Comparison
Climate Change
Fossil Fuels Depletion
Freshwater Resource Depletion
Eutrophication
Human Toxicity
Acidification
Aquatic Ecotoxicity
Stratospheric Ozone Depletion
Terrestrial Ecotoxicity
Respiratory Inorganics
Photochemical Ozone Formation
Mineral Depletion
2
1
0
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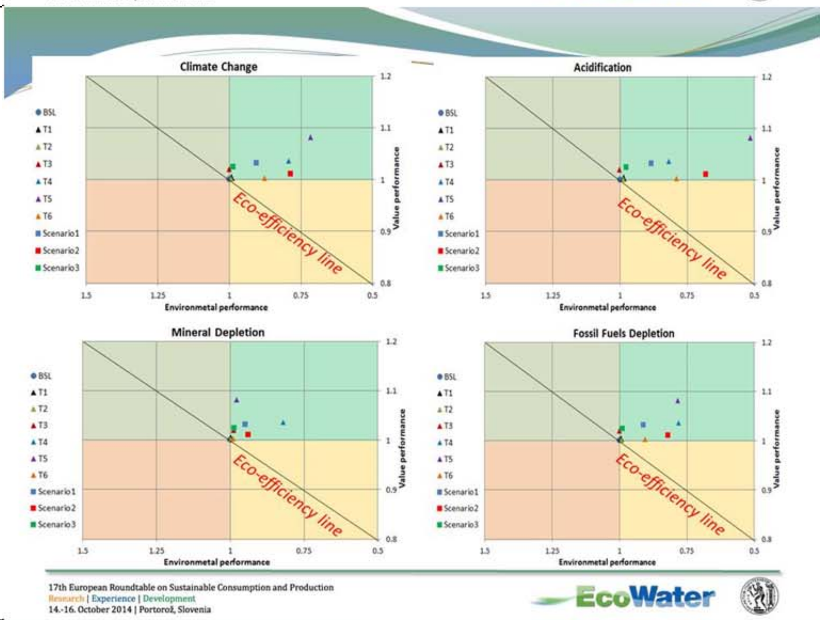

Climate Change
Acidification
Mineral Depletion
Fossil Fuels Depletion
BSL
T1
T2
T3
T4
T5
T6
Scenario1
Scenario2
Scenario3
Eco-efficiency line
Environmetal performance
Value performance
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Acknowledgments
This work was supported financially by the European Commission, 7th Framework program, EcoWater project, Grant agreement N 282882. The authors express their gratitude to "Sofiyska voda" for providing great assistance.
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For more information, see http://environ.chemeng.ntua.gr/ecowater
CIHEAM
Deltares
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO
DHI
IVL Swedish Environmental Research Institute

2.7 Towards enhancing whole-system eco-efficiency: case study of a Swiss municipal water system

Olga STEIGER[1], Christoph HUGI[1], Dionysis ASSIMACOPOULOS[2] and Les LEVIDOW[3]

[1] University of Applied Sciences Northwestern Switzerland

[2] National Technical University of Athens (NTUA), School of Chemical Engineering, Environmental and Energy Management Research Unit, Greece

[3] Open University UK

2.7.1 *Abstract*

Introduction and Methods

The EcoWater project develops and applies eco-efficiency indicators for the whole-system value chain in diverse water-use sectors to assess and support decisions to increase eco-efficiency (EcoWater 2014). Eco-efficiency evaluations generally compare net economic benefit and environmental impacts at a micro level, e.g. at a single production site, as a basis to assess different future options or scenarios. In this project the assessment encompasses all relevant stages of the whole system, especially interactions among heterogeneous actors.

Results and discussion

The EcoWater project applies the methodology to several case studies. The urban case study here is a mid-sized municipality in the Canton of Zurich. The lake plays an important role as source of raw water: 60% of drinking water stems from the lake, 40% from groundwater, but also as a sink as all treated wastewater is discharged to the lake. The net economic benefit was estimated from the surplus added to the users from water use minus total costs of the whole system to provide the drinking water and to collect and treat the wastewater. Environmental impacts were assessed through several mid-point indicators from life cycle analysis like climate change potential, eutrophication, acidification, fresh water depletion and others (cf. ISO 2012).

For the whole system's eco-efficiency, the tentative assessment was discussed in a workshop with local actors and stakeholders. As confirmed by the participants, most stages of the system (e.g. drinking-water treatment and distribution, water use by households and industry, and the wastewater treatment) are highly efficient on traditional micro-level metrics, e.g. the drinking water network losses are reduced to around 9%, the wastewater treatment plant recovers heat from wastewater and biogas is generated from sludge and used in a CHP plant. Options for further improvement include water recycling and reuse.

Going beyond current quality standards, new legislation will require approx. 100 out of Switzerland's more than 700 WWTPs to reduce the currently discharged micro-pollutants load by half. According to the eco-efficiency analysis, available technologies would increase overall costs through capital investment and operational costs and also increase some emissions, while reducing environmental impacts of micro-pollutants. Minor cost savings can be expected in the case of direct reuse of the treated water. As the important overall result, the eco-efficiency increase for micro-pollutants removal is high, while the negative changes in the climate change and the freshwater ecosystem indicator are moderate.

Conclusions

The EcoWater method helps to identify potential stages of a system for improving whole-system eco-efficiency, by comparing specific options with the baseline

situation. The results help to coordinate discussions among multiple stakeholders. To facilitate implementation, the project will explore integration into the well-known framework of river basin management.

References
EcoWater (2014): EcoWater project website: http://environ.chemeng.ntua.gr/ecoWater
ISO (2012): ISO 14045: Environmental management - Eco-efficiency assessment of product systems - Principles, requirements and guidelines. International Organisation for Standardisation

Keywords

Eco-efficiency indicators, municipal water systems, urban case study

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Prof. HUGI, Christoph; University of Applied Sciences Northwestern Switzerland

2.7.2 Presentation

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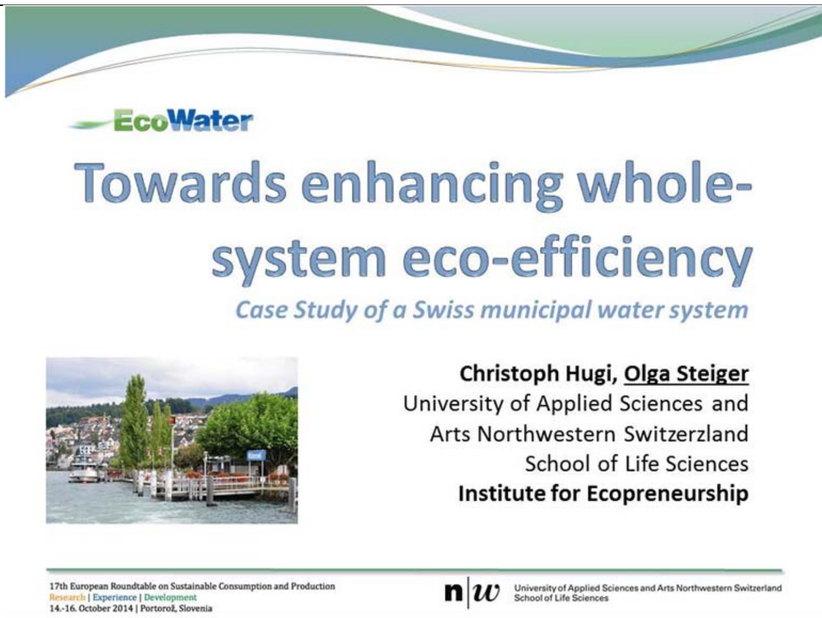

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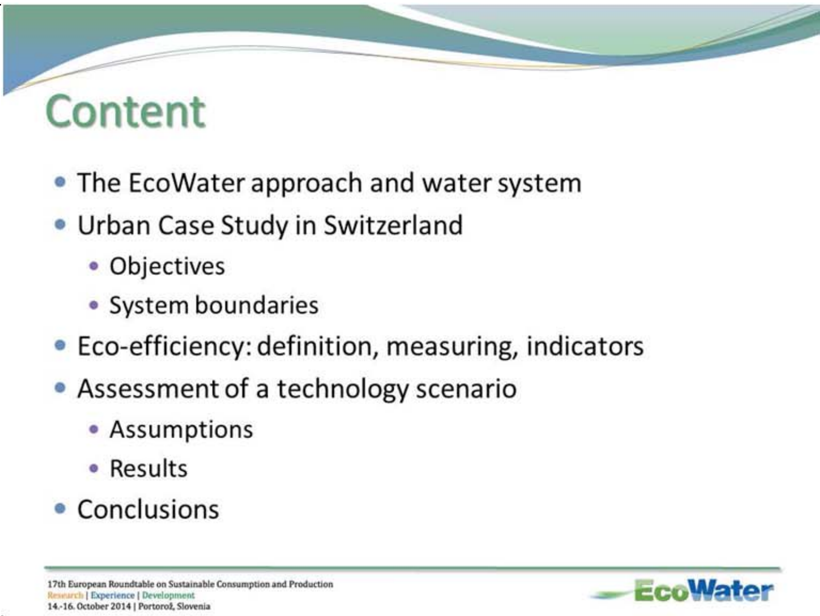

Content
The EcoWater approach and water system
Urban Case Study in Switzerland
Objectives
System boundaries
Eco-efficiency: definition, measuring, indicators
Assessment of a technology scenario
Assumptions
Results
Conclusions
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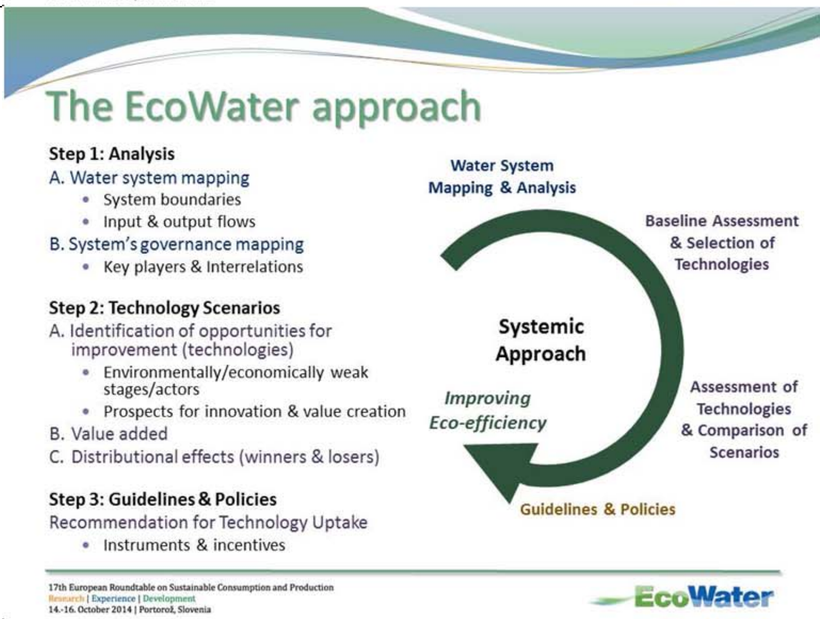

The EcoWater approach
Step 1: Analysis
A. Water system mapping
System boundaries
Input & output flows
B. System's governance mapping
Key players & Interrelations
Step 2: Technology Scenarios
A. Identification of opportunities for improvement (technologies)
Environmentally/economically weak stages/actors
Prospects for innovation & value creation
B. Value added
C. Distributional effects (winners & losers)
Step 3: Guidelines & Policies
Recommendation for Technology Uptake
Instruments & incentives
Water System Mapping & Analysis
Baseline Assessment & Selection of Technologies
Systemic Approach
Improving Eco-efficiency
Assessment of Technologies & Comparison of Scenarios
Guidelines & Policies
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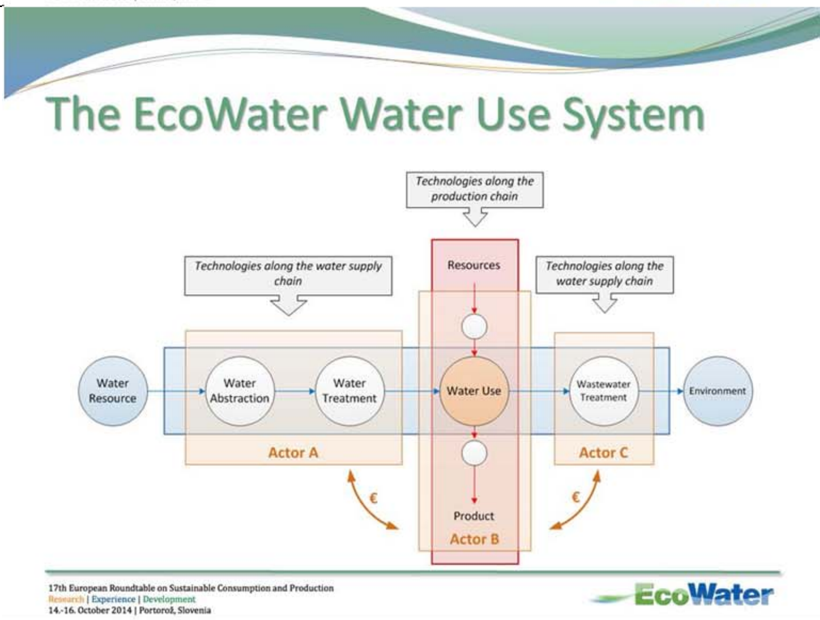

The EcoWater Water Use System
Technologies along the production chain
Technologies along the water supply chain
Technologies along the water supply chain
Resources
Water Resource
Water Abstraction
Water Treatment
Water Use
Wastewater Treatment
Environment
Actor A
Actor C
€
€
Product
Actor B
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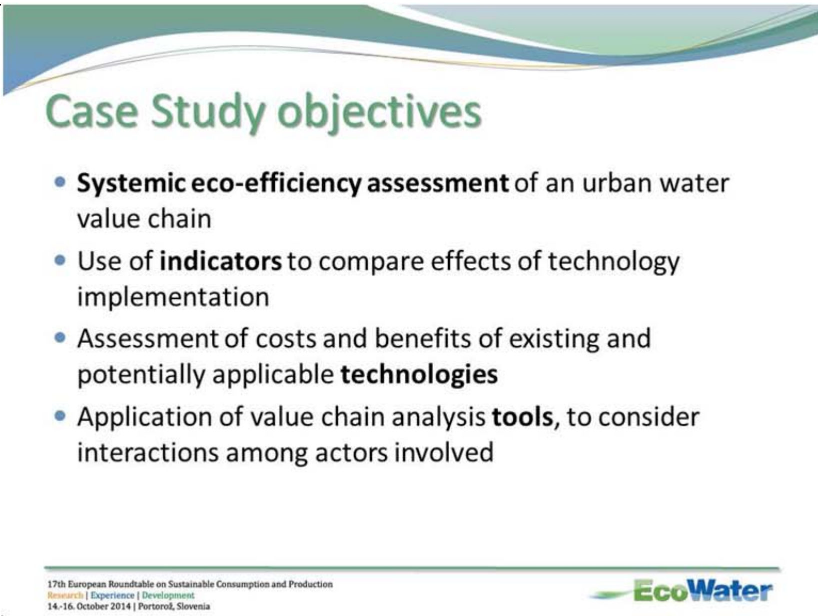
Case Study objectives
Systemic eco-efficiency assessment of an urban water value chain
Use of indicators to compare effects of technology implementation
Assessment of costs and benefits of existing and potentially applicable technologies
Application of value chain analysis tools, to consider interactions among actors involved
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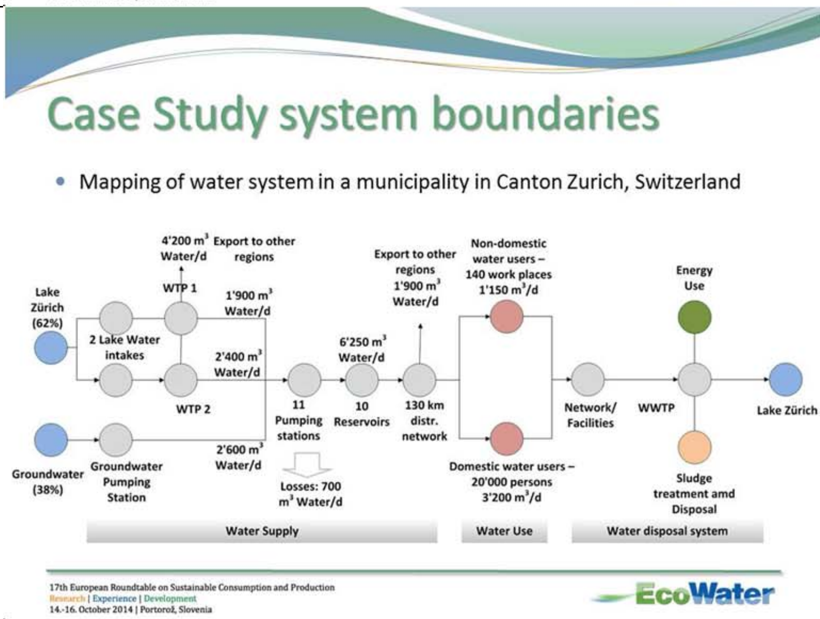
Case Study system boundaries
Mapping of water system in a municipality in Canton Zurich, Switzerland
4'200 m³ Water/d
Export to other regions
WTP 1
1'900 m³ Water/d
Lake Zürich (62%)
2 Lake Water intakes
2'400 m³ Water/d
WTP 2
Groundwater (38%)
Groundwater Pumping Station
2'600 m³ Water/d
11 Pumping stations
Losses: 700 m³ Water/d
6'250 m³ Water/d
10 Reservoirs
Export to other regions 1'900 m³ Water/d
130 km distr. network
Non-domestic water users – 140 work places 1'150 m³/d
Domestic water users – 20'000 persons 3'200 m³/d
Network/ Facilities
WWTP
Energy Use
Sludge treatment amd Disposal
Lake Zürich
Water Supply
Water Use
Water disposal system
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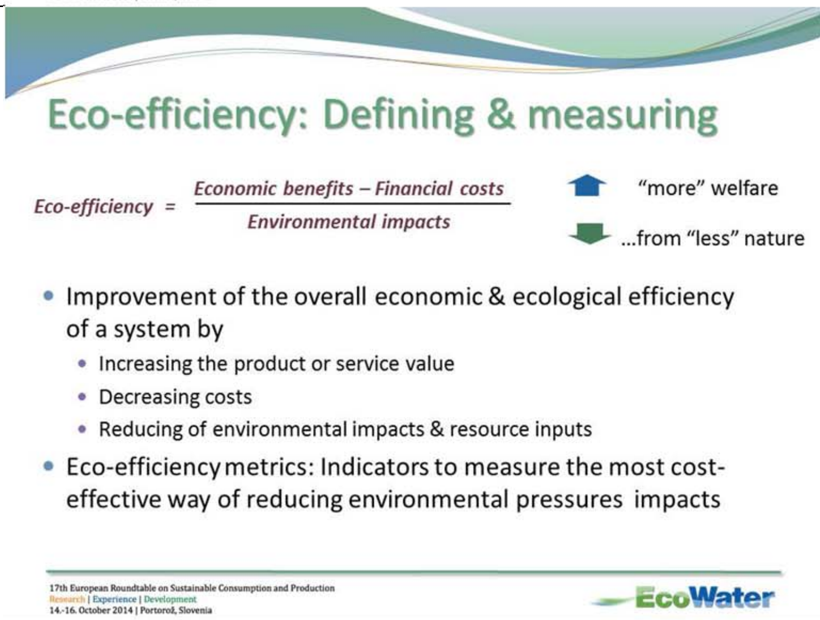
Eco-efficiency: Defining & measuring
Eco-efficiency = Economic benefits – Financial costs / Environmental impacts
"more" welfare
...from "less" nature
Improvement of the overall economic & ecological efficiency of a system by
Increasing the product or service value
Decreasing costs
Reducing of environmental impacts & resource inputs
Eco-efficiency metrics: Indicators to measure the most cost-effective way of reducing environmental pressures impacts
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Eco-efficiency indicators

$$\text{Eco-efficiency indicator} = \frac{\text{Economic benefits} - \text{Financial Costs}}{\text{Environmental impacts}} = \frac{TVA}{EI}$$

Economic Indicator	Unit
Total Value Added (TVA)	€/y

Environmental Indicators	Unit
Freshwater resource depletion	m^3/y
Micropollutants released	kg/y
Climate change	$tCO_{2,eq}/y$
...	

=

Eco-efficiency Indicators	Unit
Freshwater resource depletion	€/m^3
Micropollutants released	€/kg
Climate change	€/$tCO_{2,eq}$
...	

Calculation of baseline eco-efficiency as basis for improvements

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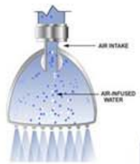
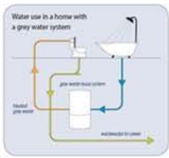
Assessment of a technology scenario

- **Toilets**: Water saving appliances for cold water – ultra low-flush toilets
- **Showers**: Water saving appliances for warm water – water saving shower heads
- **Greywater**: Water reuse and recycling technology



(bricor, 2013)

(hgtv, 2014)



(Guelph, 2013)

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Assumptions for Environmental performance

- **Ultra-low flush toilets**
  - No 12-litres toilets are used anymore
  - Share 8-litres toilets decreases from 50% to 30%
  - Share of households with 4-litres toilets increases from 5% to 70%
  - **Result: 20% less consumption of cold water**
- **Water saving showerheads**
  - Share of population using the new technology rises from 30% in the baseline to 60%
  - **Result: 9% less consumption of hot water**
- **Greywater recycling technology**
  - Implementation of technology by 10% of households
  - Technology needs extra electricity for the operation, which is 1% more than in the baseline

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Costs and savings of households

Parameter	Toilets	Showers	Greywater	Unit
Investment costs				
Investment costs	850,000	27,300	764,000	€
Lifetime	30	10	15	years
Interest rate	2.5	2.5	2.5	%/year
Annualised investment costs	40,611	3,119	61,706	€/year
Annual operation and maintenance cost				
Fixed costs (incl. maintenance)	0	0	11,000	€/year
Cost of productive inputs (electr.)	0	0	3,982	€/year
Annual savings				
Savings in costs for drinking water	-195,934	-26,718	-19,166	€/year
Savings in costs for wastewater	-211,031	-28,777	-20,643	€/year
Savings in costs for energy	n.a.	-103,790	0	€/year
Total annual additional costs (+)/ savings (-)				
Total saving			**-485,641**	**€/year**

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Environmental performance

Indicator	Baseline	Technology scenario	Change
Climate Change (tCO2eq)	4,905,334	4,598,784	-6%
Fossil Fuels Depletion (MJ)	95,093,418	89,405,149	-6%
Freshwater Resource Depletion (m3)	79,388	69,438	-13%
Eutrophication (kgPO4eq)	505,501	474,476	-6%
Human Toxicity (kg1,4-DBeq)	558,840	524,260	-6%
Acidification (kgSO2eq)	11,683	11,002	-6%
Aquatic Ecotoxicity (kg1,4-DBeq)	161,070	150,895	-6%
Stratospheric Ozone Depletion (kgCFC-11eq)	1.0129	0.9518	-6%
Terrestrial Ecotoxicity (kg1,4-DBeq)	418	393	-6%
Respiratory Inorganics (kgPM10,eq)	1,995	1,879	-6%
Photochemical Ozone Formation (kgC2H4,eq)	656	617	-6%
Micropollutants (kg)	60	60	0%

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Economic performance

Actor	NEO* in baseline	NEO* in technology scenario	Change
Association of communes	-	-42'000	-42'000
Municipality	93'000	-327'000	-420'000
Domestic water users	1'451'000	1'937'000	486'000
Non-domestic water users	965'000	965'000	-
Total Value Added (TVA)	**2'509'000**	**2'533'000**	**24'000**

* Net Economic Output

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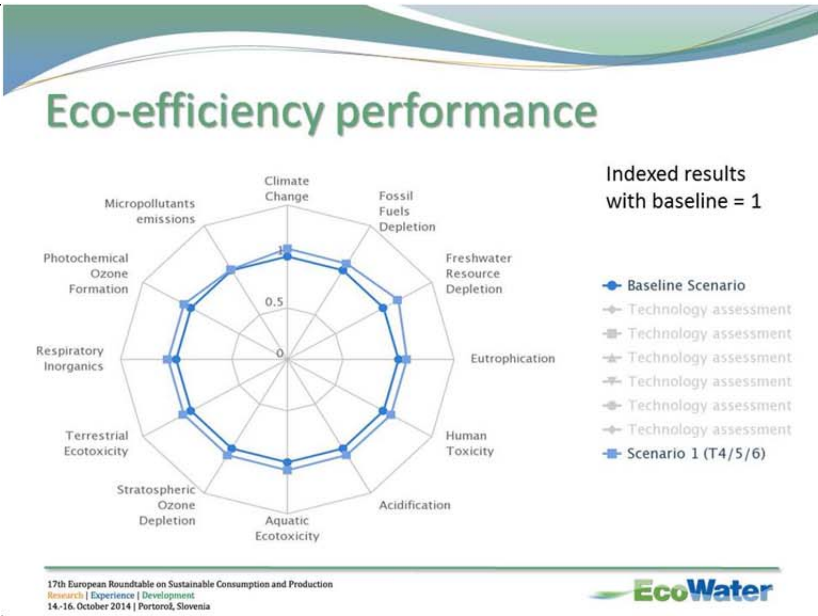
<tr><td>(14)</td><td>
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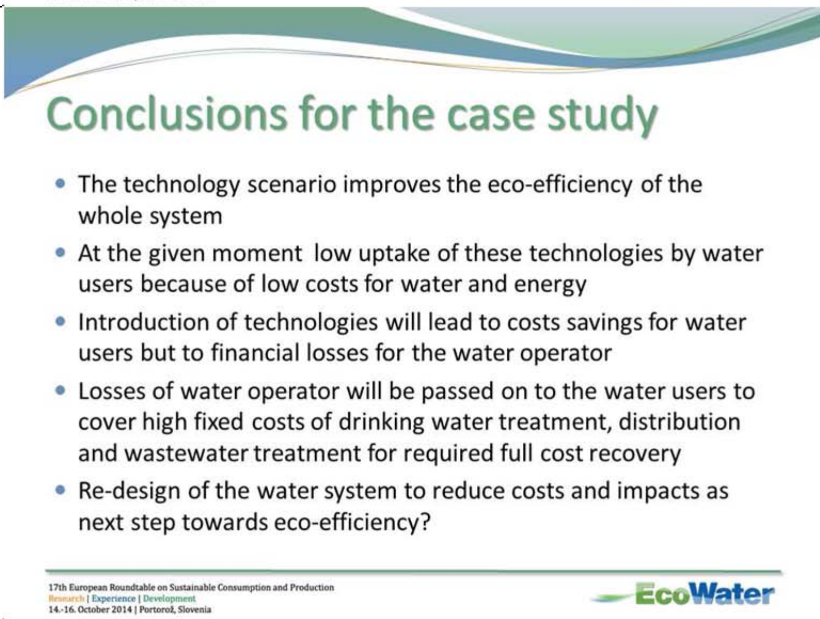
<tr><td>(15)</td><td>
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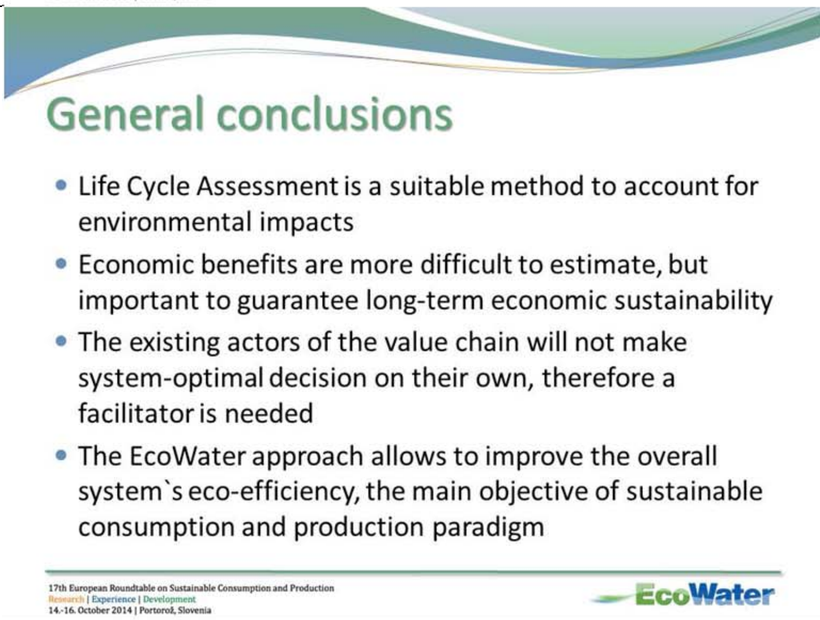
<tr><td>(16)</td><td>
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2.8 Value chain upgrading in a textile dyeing industry

Athanasios ANGELIS-DIMAKIS[1] Anastasia ALEXANDRATOU[1] and Anna BALZARINI[2] and

[1] National Technical University of Athens, Greece
[2] Geologist, Italy

2.8.1 Abstract

Eco-efficiency has been recognized over the last two decades as a measure of progress towards a greener economy as it integrates the concepts of economic welfare with the ecological impact of products or services throughout their lifecycle. Combined with the resource efficiency, eco-efficiency can lead to a more sustainable development of a given system.

The present paper examines the use of eco-efficiency indicators in a water-use system related to the industrial sector, specifically, the case of the textile industry in the region of Biella, Italy. The Biella region has traditionally been an important wool processing and textile centre. Despite the economic crisis, which has led to the closing of nearly half of the local industries during the last decade, Biella remains one of the more distinguished production centres of wool fabrics for clothing and fine fibres, with more than 500 active industrial units. For the purpose of the analysis, two representative units are selected; one standard chemical dyeing unit with in-house wastewater treatment and one natural dyeing unit, connected to the municipal wastewater network.

Their environmental performance is assessed by using nine relevant environmental midpoint impact categories, while the economic performance is measured by using the total value added to the system’s final product due to water use. The assessment of the baseline scenario underlines the most significant environmental problems; increased human toxicity, aquatic and terrestrial ecotoxicity due to the use of dyeing chemicals, and extensive aquatic freshwater depletion resulting from the dye-ing process.

Prospects for improving the system’s overall eco-efficiency are also investigated. Through the identification of the environmentally weak stages of the system, as well as the selection and implementation of innovative technologies that would upgrade the value chain, two alternative technology scenarios are formulated and compared to the baseline scenario.

The first scenario aims to increase the resource efficiency, related to energy and water consumption, through a set of technologies applicable to water abstraction and dyeing processes. The second one focuses on water pollution prevention, through the implementation of technologies that improve the quality of textile wastewater released to the environment, combined with the partial replacement of chemical dyeing with natural dyeing.

The analysis reveals that both scenarios improve the overall eco-efficiency of the system, each in a different way. The main impact of the first scenario on the system’s environmental performance is the reduction of freshwater and abiotic resource depletion, by increasing the values of the eco-efficiency indicators. The second scenario, aiming at pollution prevention, improves all three toxicity indicators. Human toxicity, aquatic and terrestrial ecotoxicity indicators show a significant increase.

Keywords
Eco-efficiency, toxicity, resource efficiency, textile wastewater, pollution prevention

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Ms. BALZARINI, Anna; Geologist, Italy

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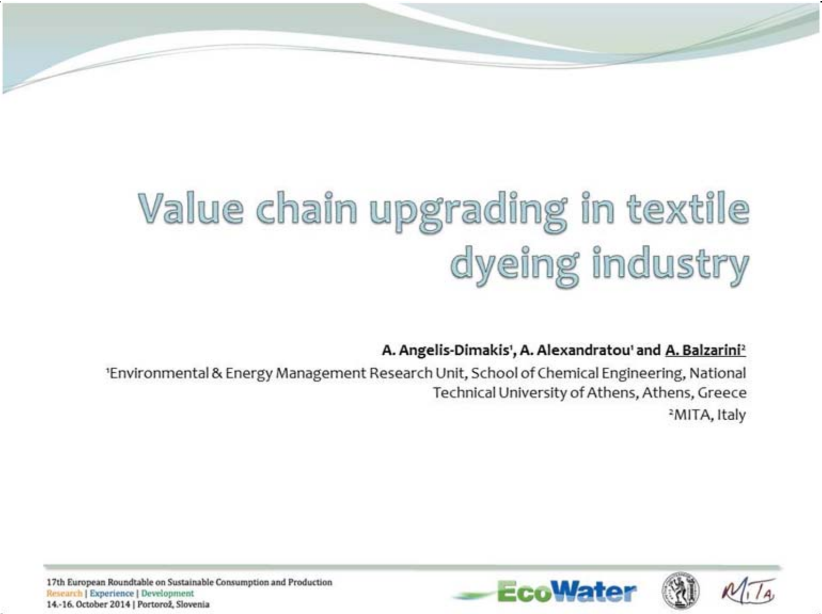
<tr><td>(1)</td><td></td><td>
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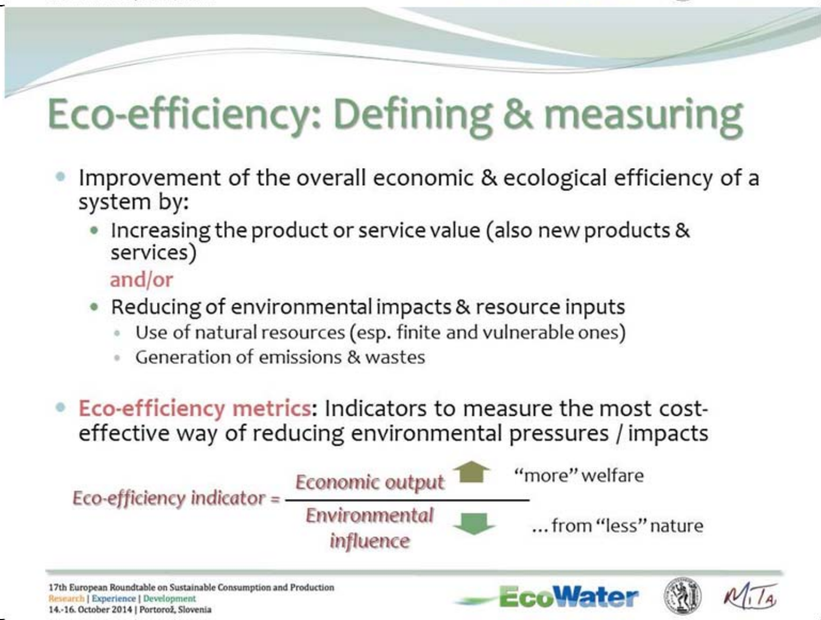
<tr><td>(2)</td><td></td><td>
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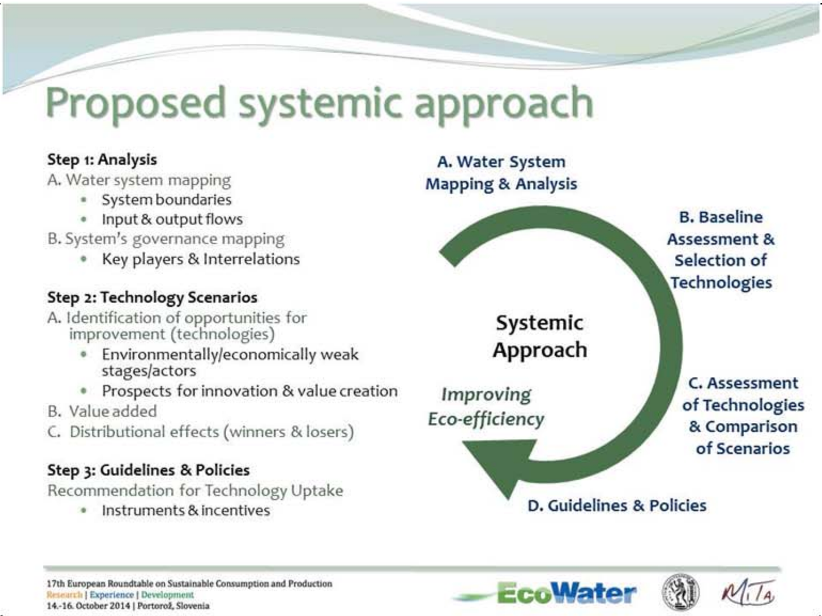

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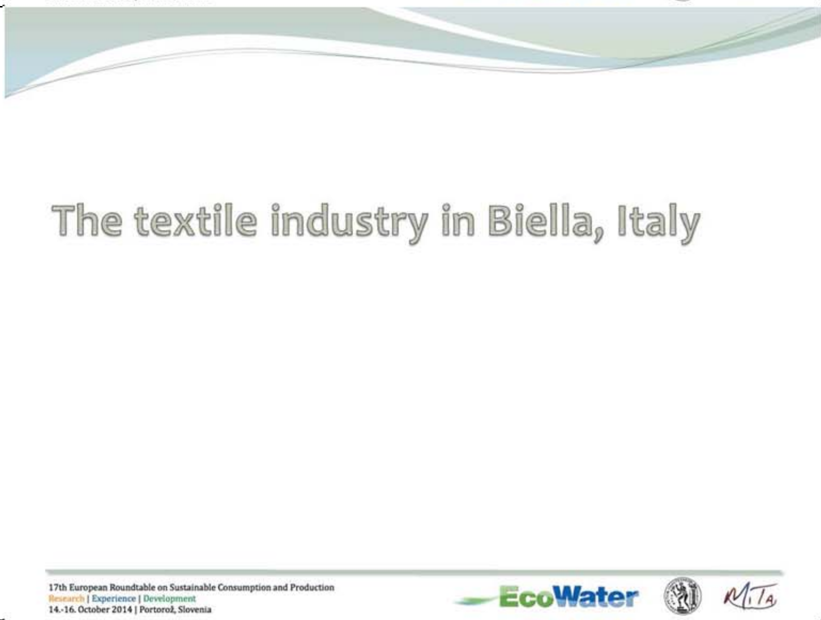

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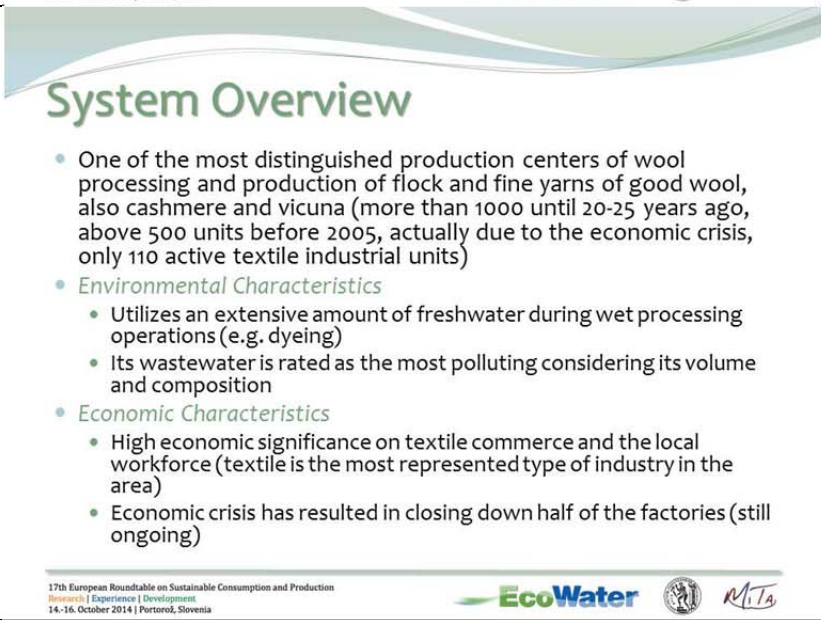

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Actors' Overview

- The regional authorities, responsible for the water survey and river basin control
- The textile industry, including:
  - A unit with in-house wastewater treatment plant, where the dyeing process is done by using standard chemical methods (Unit A)
  - A unit which uses both standard chemical dyes and natural herbal dyes (in separate production lines) and is connected to the municipal wastewater network (Unit B)
- The municipalities' consortium, which is responsible for water supply and wastewater collection/treatment plant and the sewage disposal network (note: 58% industries have in-house WWTP , 42% are connected to municipal WW Network)

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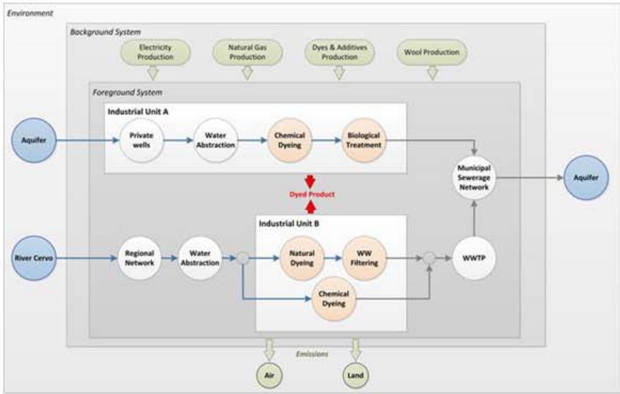
Schematic Representation



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Baseline Assessment

- Eight relevant environmental and eco-efficiency indicators
- Toxicity (human and ecotoxicity) is the most important environmental impact, followed by freshwater depletion

Environmental Indicators (Unit)	Normalized Values (Unit/m³)	Foreground Contribution	Background Contribution	Eco-efficiency Indicators (€/Unit)
Climate Change ($tCO_{2,eq}$)	0.01	51 %	49 %	1,351
Freshwater Depletion (m^3)	0.15	100 %	0 %	122
Eutrophication ($kgPO_4^{-3}{}_{,eq}$)	0.02	90 %	10 %	1,025
Human Toxicity ($kg1,4\text{-}DB_{,eq}$)	2.68	73 %	27 %	6.8
Acidification ($kgSO_2^{-}{}_{,eq}$)	0.05	19 %	81 %	366
Aquatic Ecotoxicity ($kg1,4\text{-}DB_{,eq}$)	22.45	99 %	1 %	0.8
Terrestrial Ecotoxicity ($kg1,4\text{-}DB_{,eq}$)	1.94	99 %	1 %	9.5
Photochemical Ozone Formation ($kgC_2H_{4,eq}$)	$<10^{-3}$	18 %	82 %	6.959

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Value Chain Upgrading
Low-Liquor-Ratio Jet Dyeing
Based on the principle of accelerating water through a venturi constriction to transport fabrics
Environmental Performance
Abstracted water is decreased by 50%
Energy consumption is decreased by 40%
Quantity of dyes and additives is decreased by 20%.
Economic Performance
Investment Cost: 150.000-300.000€
O&M Cost: 20.000€
Lifetime: 10 years
Automatic dispensing
Automatic weighing, dissolving, and measuring systems in order to facilitate the precise delivery of textile chemicals and dyes
Environmental Performance
Abstracted water and energy and dyes consumed are reduced by 15%
Economic Performance
Investment Cost: 150.000-300.000€
O&M Cost: 20.000€
Lifetime: 15 years
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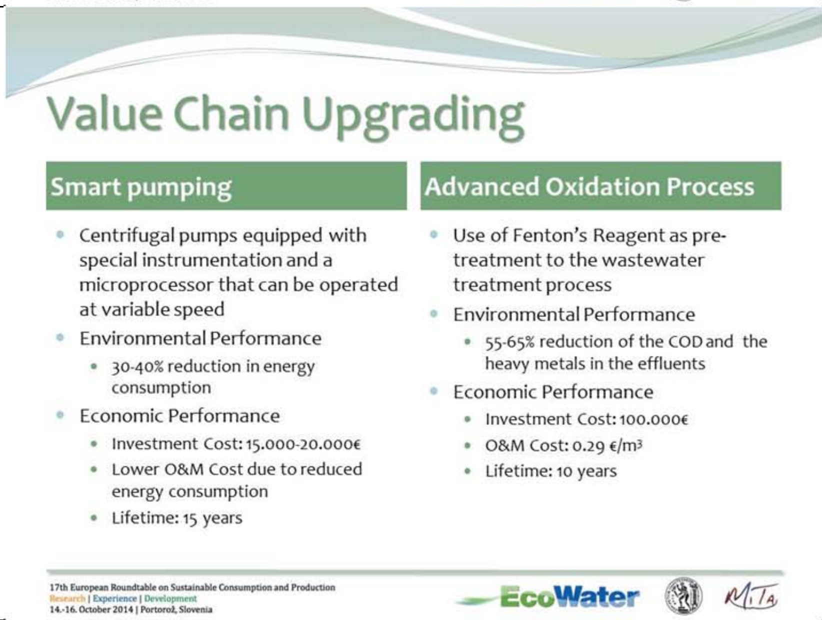
Value Chain Upgrading
Smart pumping
Centrifugal pumps equipped with special instrumentation and a microprocessor that can be operated at variable speed
Environmental Performance
30-40% reduction in energy consumption
Economic Performance
Investment Cost: 15.000-20.000€
Lower O&M Cost due to reduced energy consumption
Lifetime: 15 years
Advanced Oxidation Process
Use of Fenton's Reagent as pre-treatment to the wastewater treatment process
Environmental Performance
55-65% reduction of the COD and the heavy metals in the effluents
Economic Performance
Investment Cost: 100.000€
O&M Cost: 0.29 €/m3
Lifetime: 10 years
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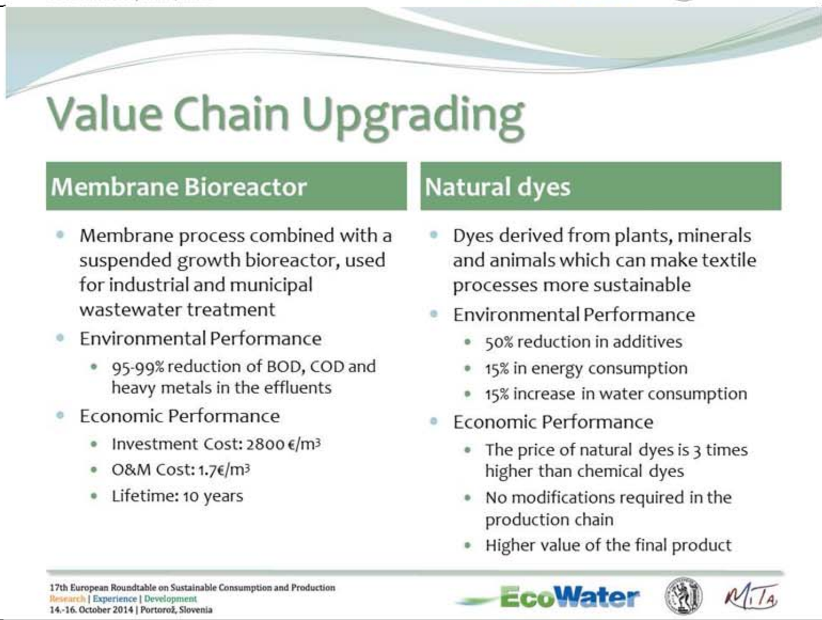
Value Chain Upgrading
Membrane Bioreactor
Membrane process combined with a suspended growth bioreactor, used for industrial and municipal wastewater treatment
Environmental Performance
95-99% reduction of BOD, COD and heavy metals in the effluents
Economic Performance
Investment Cost: 2800 €/m3
O&M Cost: 1.7€/m3
Lifetime: 10 years
Natural dyes
Dyes derived from plants, minerals and animals which can make textile processes more sustainable
Environmental Performance
50% reduction in additives
15% in energy consumption
15% increase in water consumption
Economic Performance
The price of natural dyes is 3 times higher than chemical dyes
No modifications required in the production chain
Higher value of the final product
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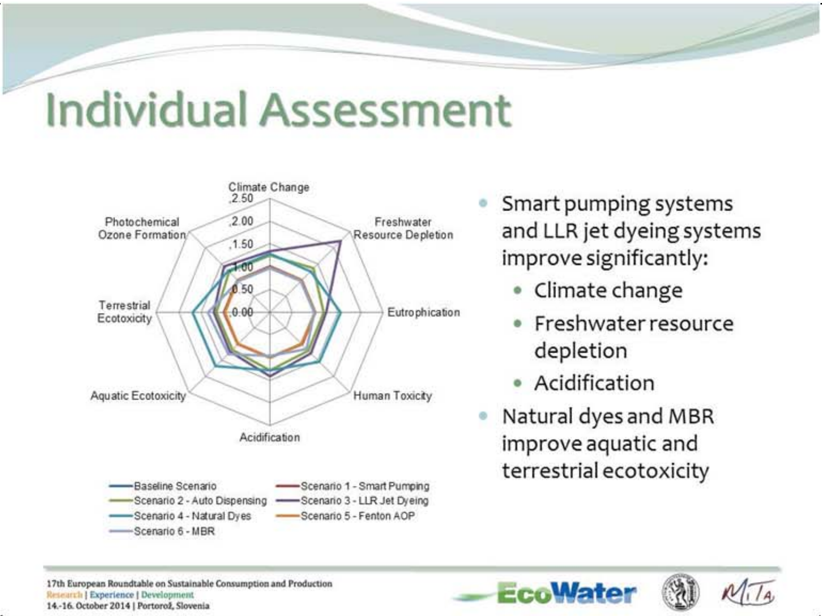
Individual Assessment
Climate Change
2.50
2.00
1.50
1.00
0.50
0.00
Freshwater Resource Depletion
Eutrophication
Human Toxicity
Acidification
Aquatic Ecotoxicity
Terrestrial Ecotoxicity
Photochemical Ozone Formation
Baseline Scenario
Scenario 1 - Smart Pumping
Scenario 2 - Auto Dispensing
Scenario 3 - LLR Jet Dyeing
Scenario 4 - Natural Dyes
Scenario 5 - Fenton AOP
Scenario 6 - MBR
Smart pumping systems and LLR jet dyeing systems improve significantly:
Climate change
Freshwater resource depletion
Acidification
Natural dyes and MBR improve aquatic and terrestrial ecotoxicity
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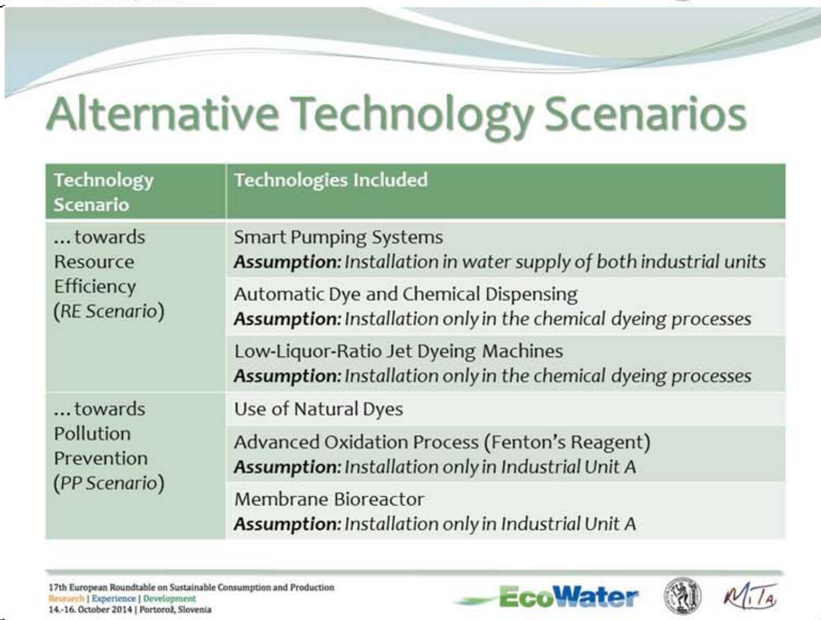
Alternative Technology Scenarios
Technology Scenario
Technologies Included
...towards Resource Efficiency (RE Scenario)
Smart Pumping Systems
Assumption: Installation in water supply of both industrial units
Automatic Dye and Chemical Dispensing
Assumption: Installation only in the chemical dyeing processes
Low-Liquor-Ratio Jet Dyeing Machines
Assumption: Installation only in the chemical dyeing processes
...towards Pollution Prevention (PP Scenario)
Use of Natural Dyes
Advanced Oxidation Process (Fenton's Reagent)
Assumption: Installation only in Industrial Unit A
Membrane Bioreactor
Assumption: Installation only in Industrial Unit A
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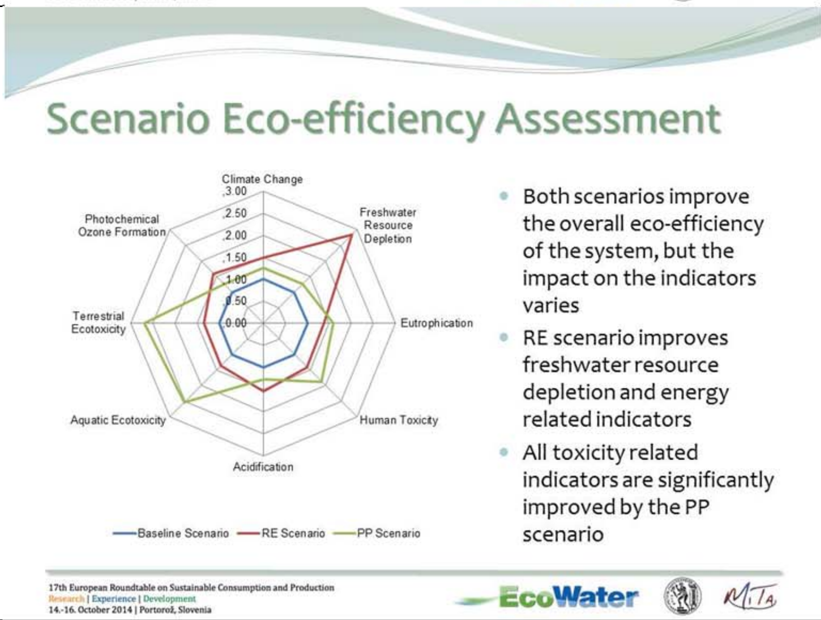
Scenario Eco-efficiency Assessment
Climate Change
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Freshwater Resource Depletion
Eutrophication
Human Toxicity
Acidification
Aquatic Ecotoxicity
Terrestrial Ecotoxicity
Photochemical Ozone Formation
Baseline Scenario
RE Scenario
PP Scenario
Both scenarios improve the overall eco-efficiency of the system, but the impact on the indicators varies
RE scenario improves freshwater resource depletion and energy related indicators
All toxicity related indicators are significantly improved by the PP scenario
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Economic Performance

Net Economic Output of Actors

Actors	Scenario Towards Resource Efficiency	Scenario Towards Pollution Prevention
Regional Authorities	Stable	Stable
Municipalities' Consortium	Stable	Increase
Industrial Unit A	Increase	Decrease
Industrial Unit B	Increase	Increase
TVA	**Increase**	**Increase**

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Distributional Issues – PP Scenario

- Scenario towards pollution prevention improves all eight eco-efficiency indicators and increases the TVA of the entire system.
- However, the NEO of the Industrial Unit A decreases.
  - The economic profit from the installation of new technologies does not counterbalance the investment cost.
- Similar alternative scenario could be examined
  - Joint implementation of the WWTP upgrade by more than one actor.

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Distributional Issues – RE Scenario

- Scenario towards Resource Efficiency can be implemented more easily since it:
  - Improves all 8 eco-efficiency indicators
  - Increases the TVA of the system
  - Increases (or does not affect) the NEO of all the involved actors.
- *Disadvantage:* Requires high investment cost (~400,000€) from the industrial units.
  - Given the economic conditions of the textile industry in Biella, this scenario may not be realistic.
- Certain economic incentives are required to make its implementation feasible, such as environmental taxes or subsidies.

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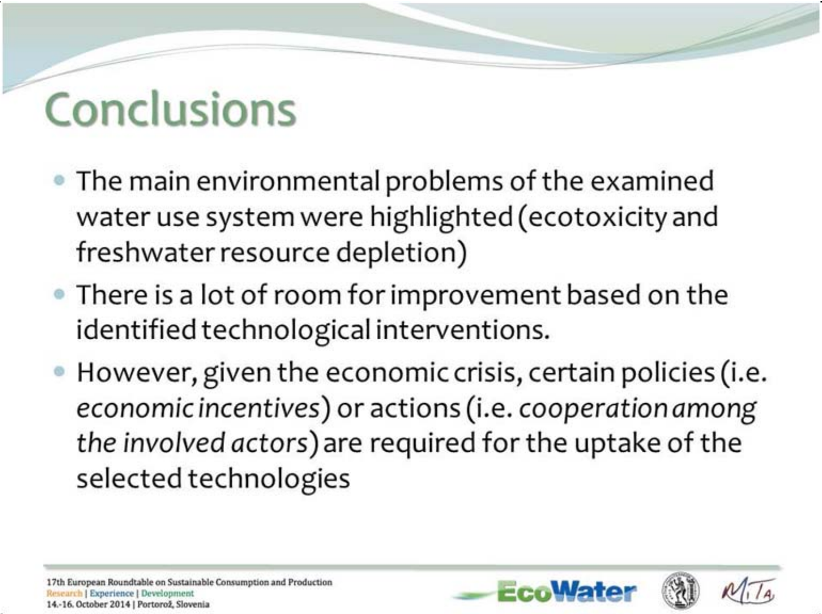
<td>
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2.9 Improving resource and eco-efficiency of an electricity-heat cogeneration plant using a systemic eco-efficiency approach

Michiel BLIND[1]
[1] Deltares, The Netherlands

2.9.1 *Abstract*

Innovative technologies and processes typically have consequences beyond the micro-level at which they are implemented. Decisions on implementing technologies should therefore take a systemic approach, including the involvement of stakeholders.

In the EcoWater project tools and methods were developed to assess whole system eco-efficiency, which is defined as the ratio of Total Value Added (TVA) and Environmental Impact (EI). The water value chain, which generically consists of water abstraction, treatment, use, waste water treatment and discharge, forms the basis of the whole system analysis. This study demonstrates the usability of the approach for a case study which core consists of a gas powered electricity-heat cogeneration plant. In this system the water value chain consists of the aforementioned stages. The water use and heat discharge are regulated, priced, and excessive heat discharge effects may have adverse effects on the receiving river basin. Today, the generated heat is used for district heating. Excess heat is mainly discharged to surface water. The TVA of the system consists of the total income generated by the system from which costs were subtracted. The EI of the system is expressed in terms of amongst others resource depletion, fresh water depletion and climate change potential, which are well-established midpoint impact categories in Life-Cycle Analysis. A proxy for EI of excess heat discharge has been developed.

A stakeholder session revealed that the main challenge regarding the use of heat are not technical, but concern the investment costs and the payback-time. The willingness to invest is dependent on trust in consistent long term policies (30-50yr), including the pricing of energy and heat, and the trust amongst the stakeholders who like in any symbiotic setting develop interdependencies. Nevertheless, technologies are required to increase the eco-efficiency, increasing the TVA, while reducing the EI.

Annually the heat demand by domestic and industry users is much higher than the electricity demand, but the demands for electricity and heat vary asynchronously during the year, complicating improving overall efficiency easily. Hence, an important challenge tackled in this case study was capturing essentials of the temporal dynamics of electricity and heat use in a simple model.

Three strategies to improve the eco-efficiency were investigated. The first

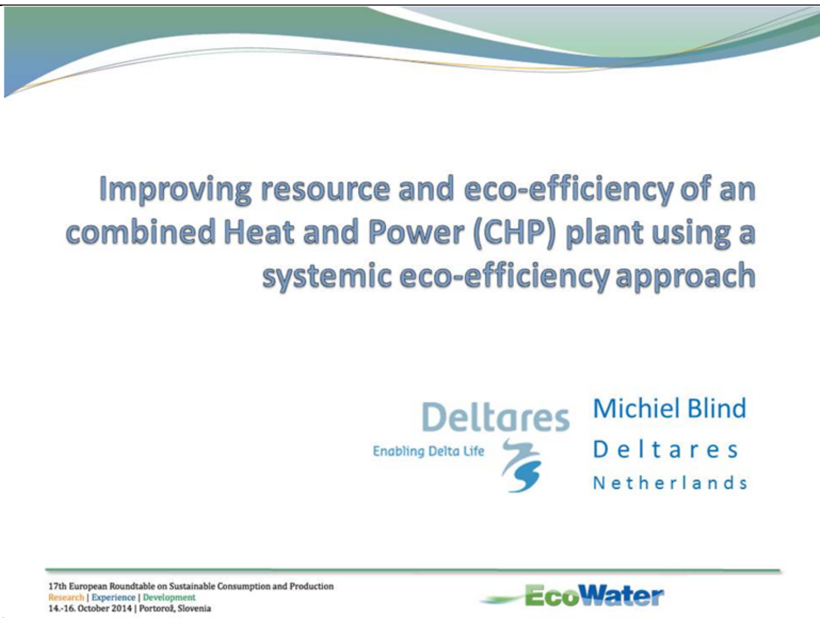
strategy concerned technologies improving the energy use of the electricity production and district heating plant and the introduction of cooling technologies. The second strategy concerned tapping higher temperature water from the electricity production, such that the heat is more useful to industry and substitutes local (fossil) fuel use for heat production. The third strategy concerned two means of ‘peak-shaving’, such that occasional shortages on heat can be met without excess low-value electricity production.

The study demonstrates that a whole system analysis provides essential insights to improve the eco-efficiency of the system. The distinction between foreground and background environmental impacts provides insights even beyond the whole system. The results show that the three option-sets have quite different effects on the overall eco-efficiency. Increasing the effective use of the energy has the most pronounced effects on TVA, the climate change potential, and the excess heat discharge. Investments in energy efficiency and cooling technologies have almost no effect.

Keywords
Resource efficiency; systemic eco-efficiency; electricity-heat cogeneration; LCA;

Corresponding Author
Mr. BLIND, Michiel; Deltares; E-mail: michiel.blind@deltares.nl

2.9.2 Presentation

(1)	

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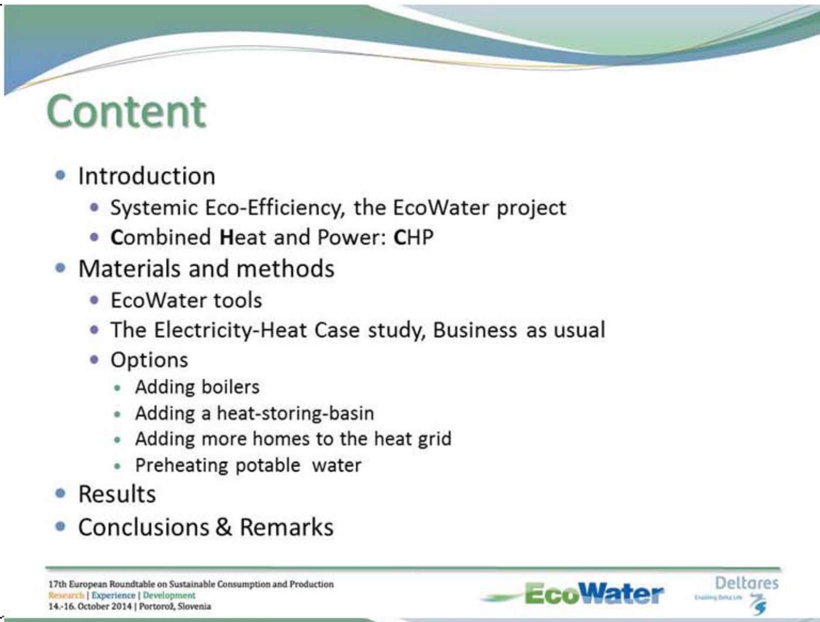
Content
Introduction
Systemic Eco-Efficiency, the EcoWater project
Combined Heat and Power: CHP
Materials and methods
EcoWater tools
The Electricity-Heat Case study, Business as usual
Options
Adding boilers
Adding a heat-storing-basin
Adding more homes to the heat grid
Preheating potable water
Results
Conclusions & Remarks
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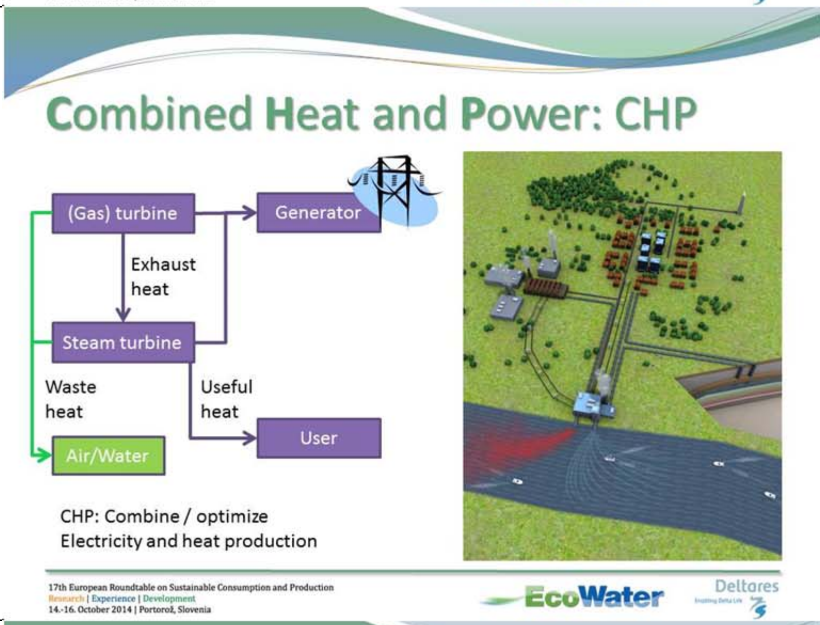
Combined Heat and Power: CHP
(Gas) turbine
Generator
Exhaust heat
Steam turbine
Waste heat
Useful heat
User
Air/Water
CHP: Combine / optimize
Electricity and heat production
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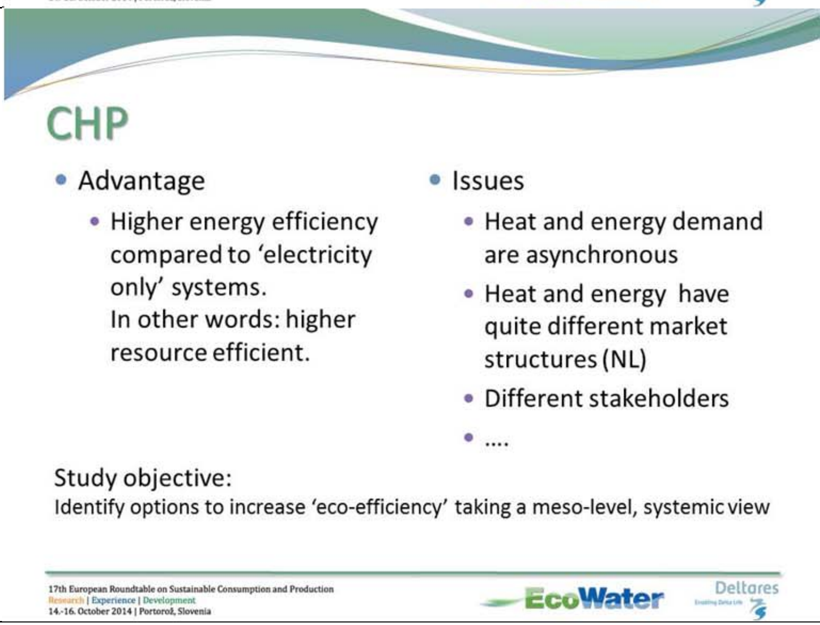
CHP
Advantage
Higher energy efficiency compared to 'electricity only' systems.
In other words: higher resource efficient.
Issues
Heat and energy demand are asynchronous
Heat and energy have quite different market structures (NL)
Different stakeholders
....
Study objective:
Identify options to increase 'eco-efficiency' taking a meso-level, systemic view
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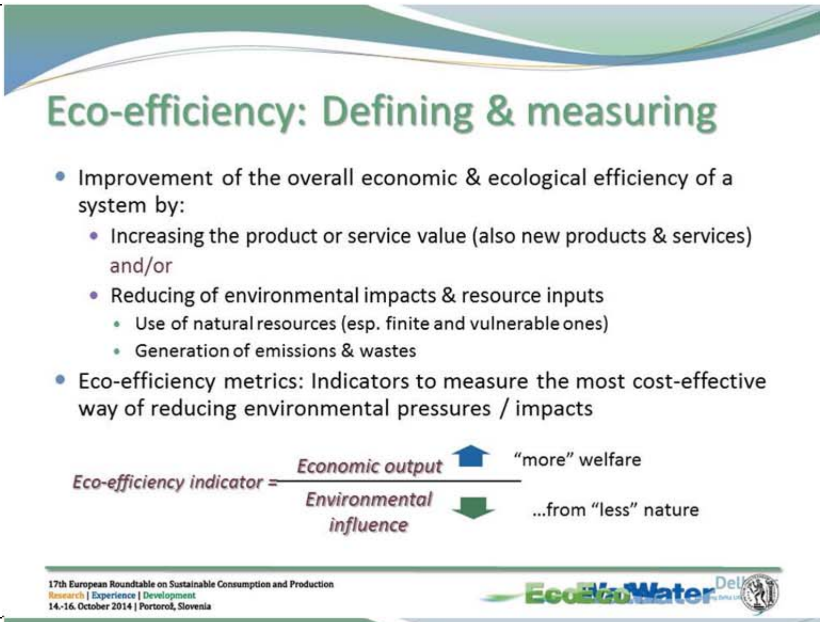
Eco-efficiency: Defining & measuring
Improvement of the overall economic & ecological efficiency of a system by:
Increasing the product or service value (also new products & services)
and/or
Reducing of environmental impacts & resource inputs
Use of natural resources (esp. finite and vulnerable ones)
Generation of emissions & wastes
Eco-efficiency metrics: Indicators to measure the most cost-effective way of reducing environmental pressures / impacts
Eco-efficiency indicator =
Economic output
Environmental influence
"more" welfare
...from "less" nature
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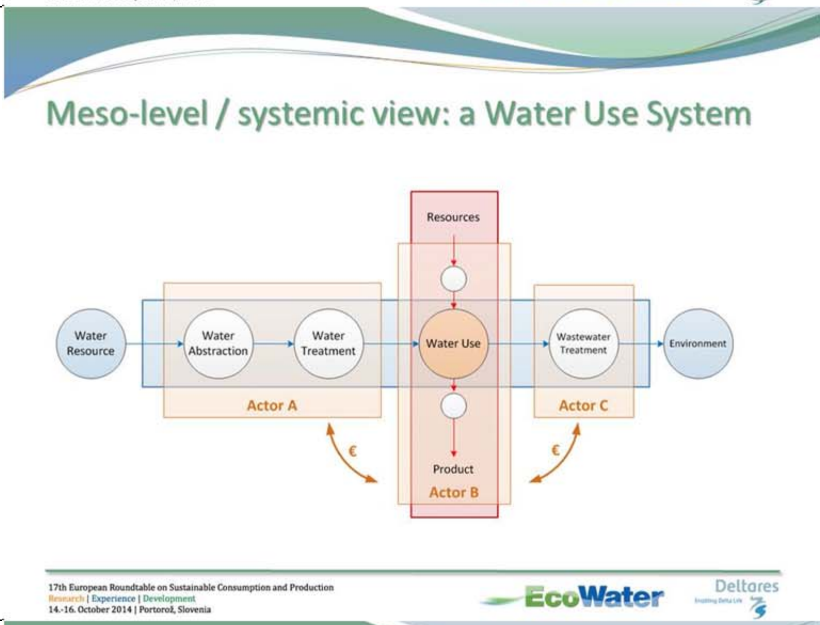
Meso-level / systemic view: a Water Use System
Resources
Water Resource
Water Abstraction
Water Treatment
Water Use
Wastewater Treatment
Environment
Actor A
Actor C
€
€
Product
Actor B
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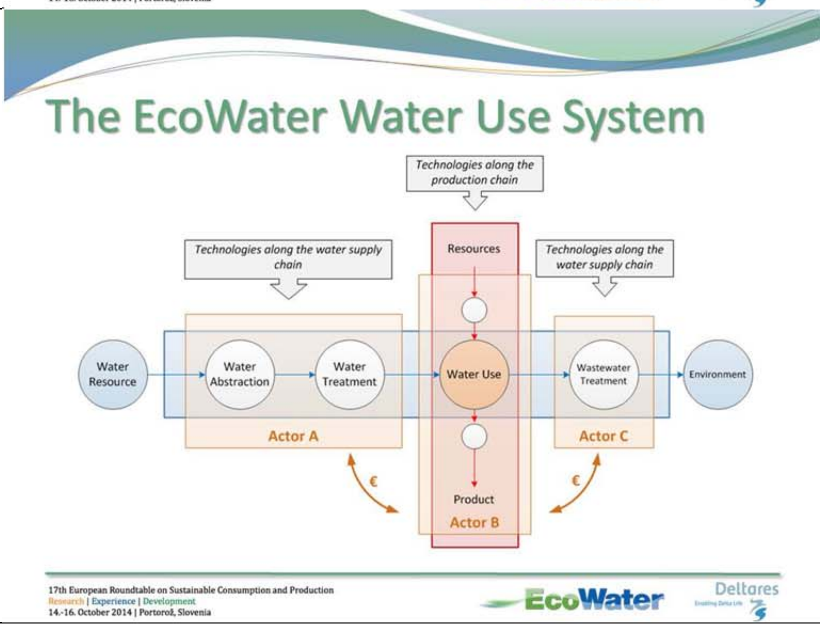
The EcoWater Water Use System
Technologies along the production chain
Technologies along the water supply chain
Technologies along the water supply chain
Resources
Water Resource
Water Abstraction
Water Treatment
Water Use
Wastewater Treatment
Environment
Actor A
Actor C
€
€
Product
Actor B
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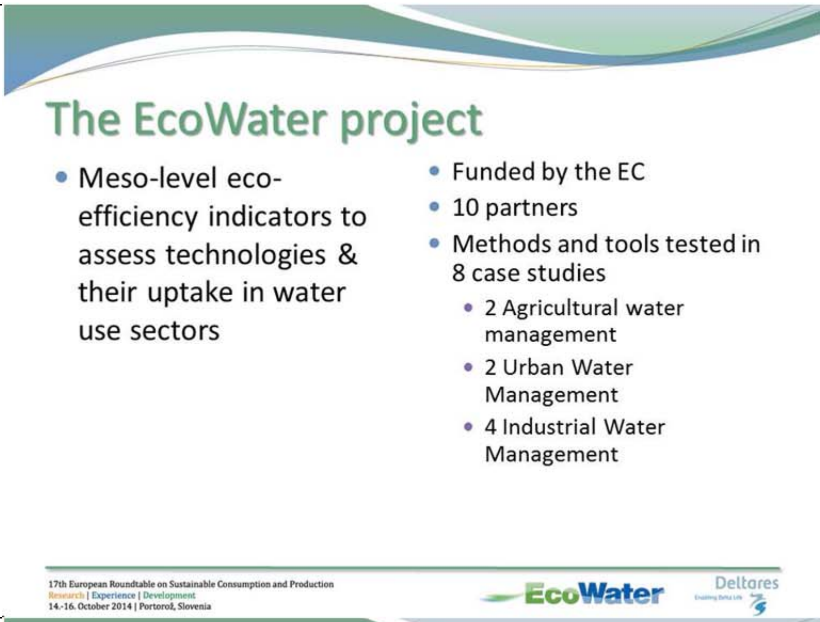
The EcoWater project
Meso-level eco-efficiency indicators to assess technologies & their uptake in water use sectors
Funded by the EC
10 partners
Methods and tools tested in 8 case studies
2 Agricultural water management
2 Urban Water Management
4 Industrial Water Management
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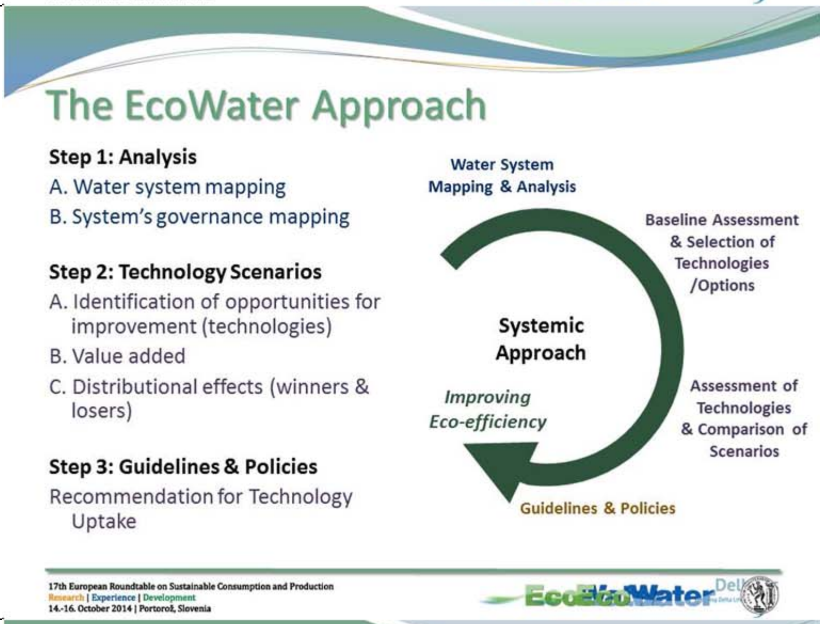
The EcoWater Approach
Step 1: Analysis
A. Water system mapping
B. System's governance mapping
Step 2: Technology Scenarios
A. Identification of opportunities for improvement (technologies)
B. Value added
C. Distributional effects (winners & losers)
Step 3: Guidelines & Policies
Recommendation for Technology Uptake
Water System Mapping & Analysis
Baseline Assessment & Selection of Technologies /Options
Systemic Approach
Improving Eco-efficiency
Assessment of Technologies & Comparison of Scenarios
Guidelines & Policies
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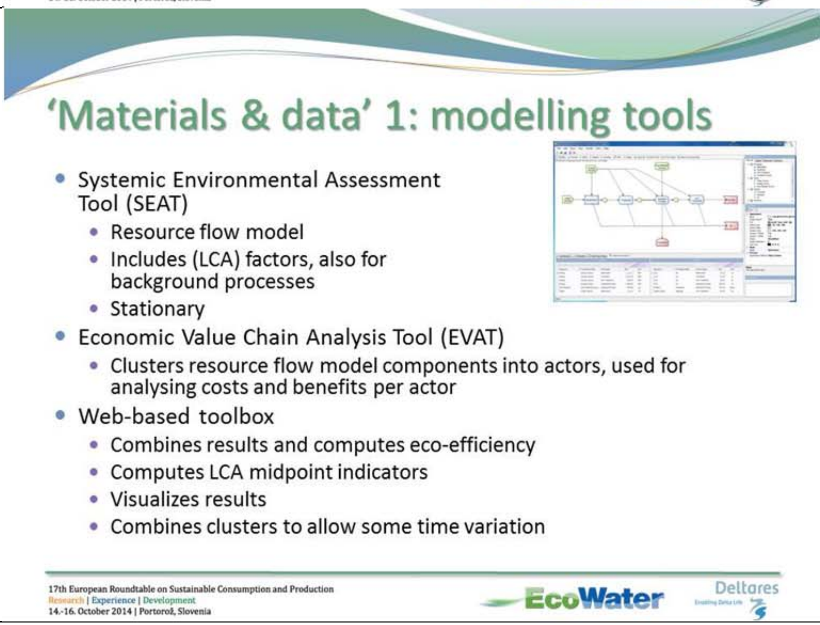
'Materials & data' 1: modelling tools
Systemic Environmental Assessment Tool (SEAT)
Resource flow model
Includes (LCA) factors, also for background processes
Stationary
Economic Value Chain Analysis Tool (EVAT)
Clusters resource flow model components into actors, used for analysing costs and benefits per actor
Web-based toolbox
Combines results and computes eco-efficiency
Computes LCA midpoint indicators
Visualizes results
Combines clusters to allow some time variation
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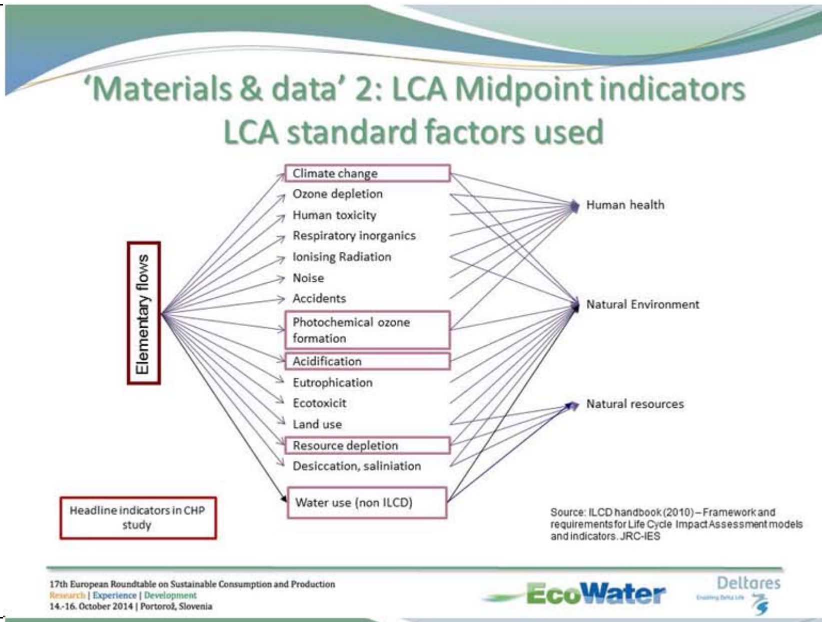

'Materials & data' 2: LCA Midpoint indicators
LCA standard factors used
Elementary flows
Climate change
Ozone depletion
Human toxicity
Respiratory inorganics
Ionising Radiation
Noise
Accidents
Photochemical ozone formation
Acidification
Eutrophication
Ecotoxicit
Land use
Resource depletion
Desiccation, saliniation
Water use (non ILCD)
Human health
Natural Environment
Natural resources
Headline indicators in CHP study
Source: ILCD handbook (2010) – Framework and requirements for Life Cycle Impact Assessment models and indicators. JRC-IES
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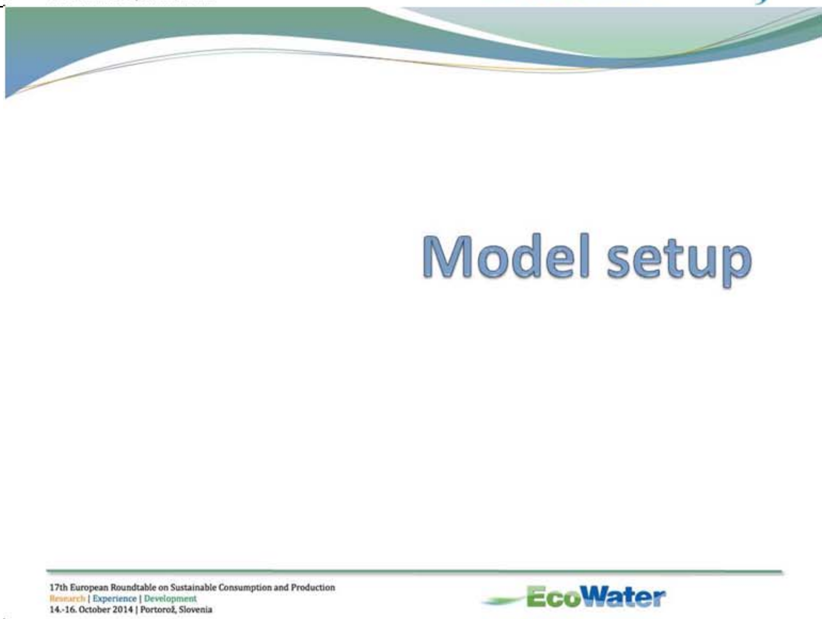

Model setup
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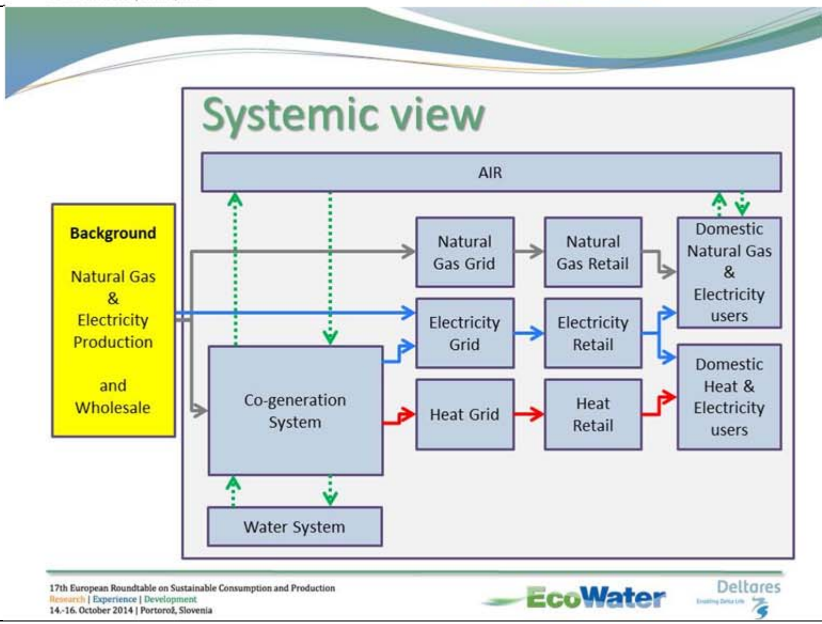

Systemic view
AIR
Background
Natural Gas & Electricity Production and Wholesale
Natural Gas Grid
Natural Gas Retail
Domestic Natural Gas & Electricity users
Electricity Grid
Electricity Retail
Domestic Heat & Electricity users
Co-generation System
Heat Grid
Heat Retail
Water System
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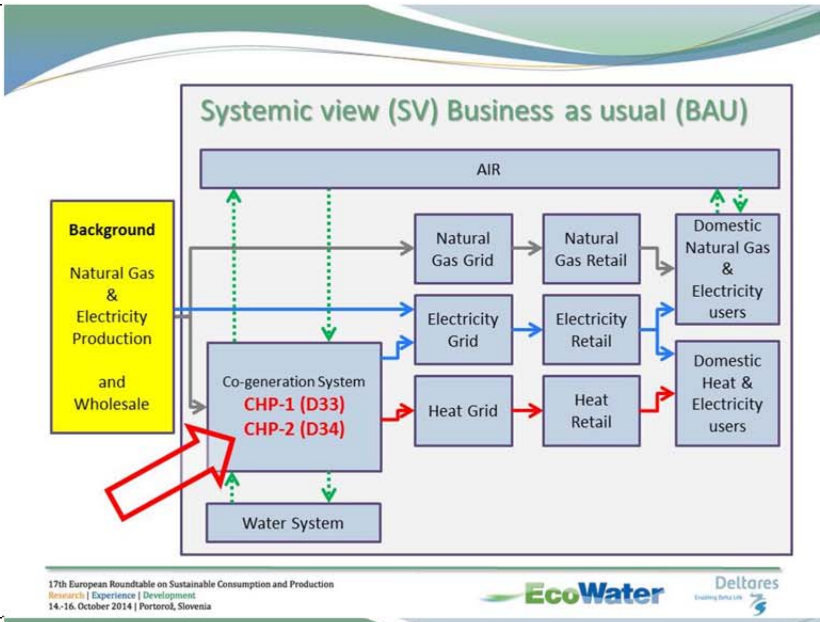
Systemic view (SV) Business as usual (BAU)
AIR
Background
Natural Gas & Electricity Production and Wholesale
Natural Gas Grid
Natural Gas Retail
Domestic Natural Gas & Electricity users
Electricity Grid
Electricity Retail
Co-generation System
CHP-1 (D33)
CHP-2 (D34)
Heat Grid
Heat Retail
Domestic Heat & Electricity users
Water System
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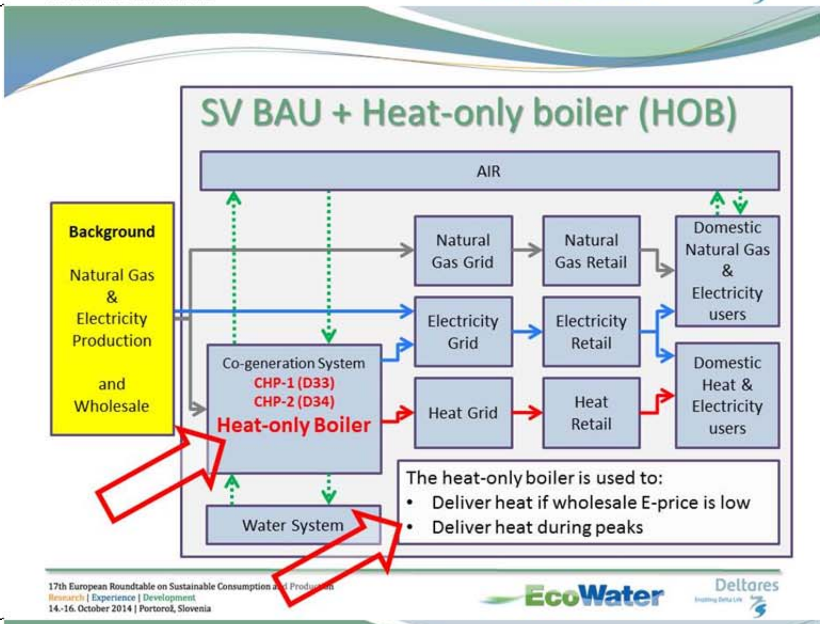
SV BAU + Heat-only boiler (HOB)
AIR
Background
Natural Gas & Electricity Production and Wholesale
Natural Gas Grid
Natural Gas Retail
Domestic Natural Gas & Electricity users
Electricity Grid
Electricity Retail
Co-generation System
CHP-1 (D33)
CHP-2 (D34)
Heat-only Boiler
Heat Grid
Heat Retail
Domestic Heat & Electricity users
Water System
The heat-only boiler is used to:
• Deliver heat if wholesale E-price is low
• Deliver heat during peaks
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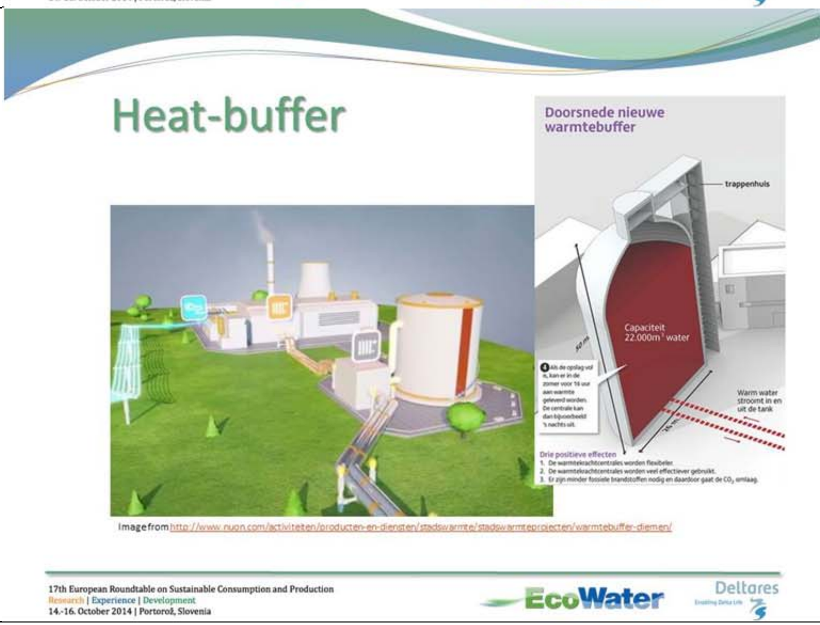
Heat-buffer
Doorsnede nieuwe warmtebuffer
trappenhuis
Capaciteit 22.000m³ water
Warm water stroomt in en uit de tank
Drie positieve effecten
Image from http://www.nuon.com/activiteiten/producten-en-diensten/stadswarmte/stadswarmteprojecten/warmtebuffer-diemen/
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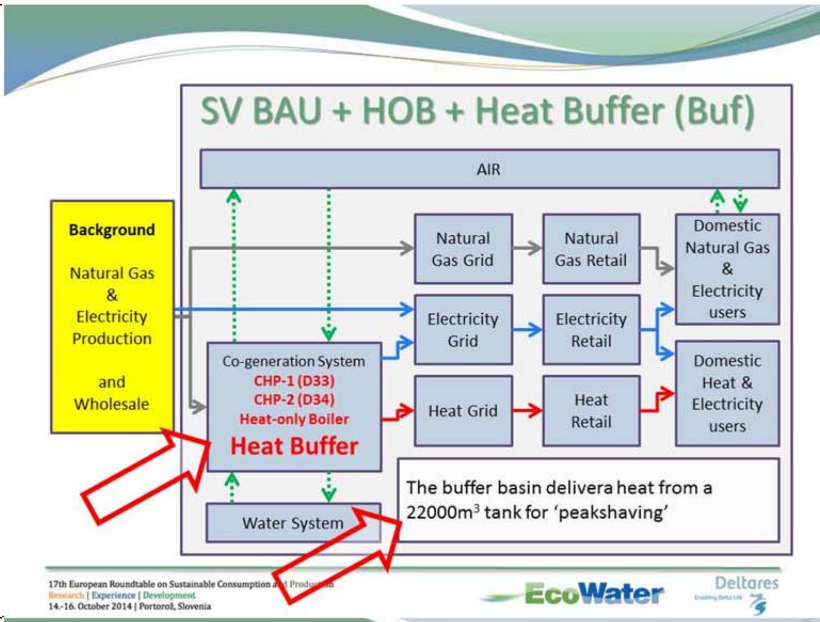
<tr><td></td><td>(17)</td><td>
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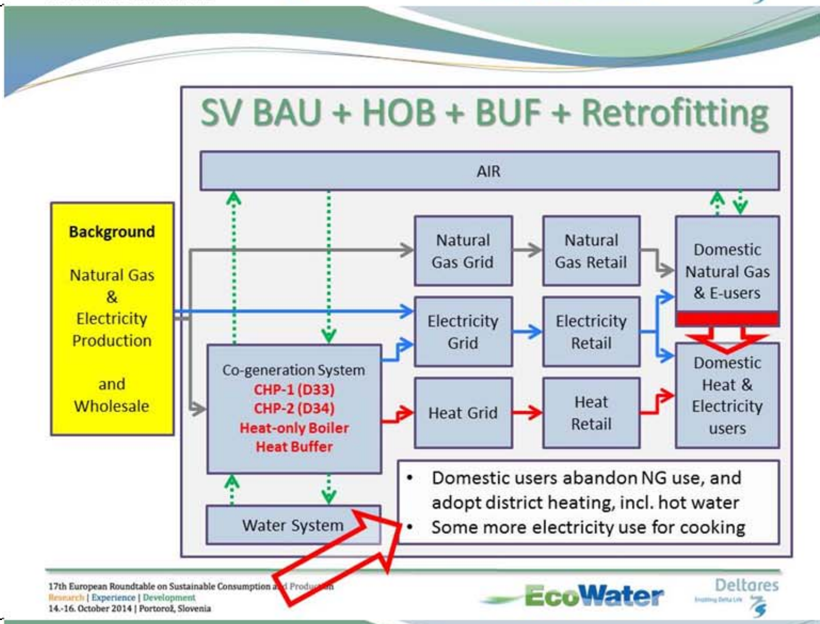
<tr><td></td><td>(18)</td><td>
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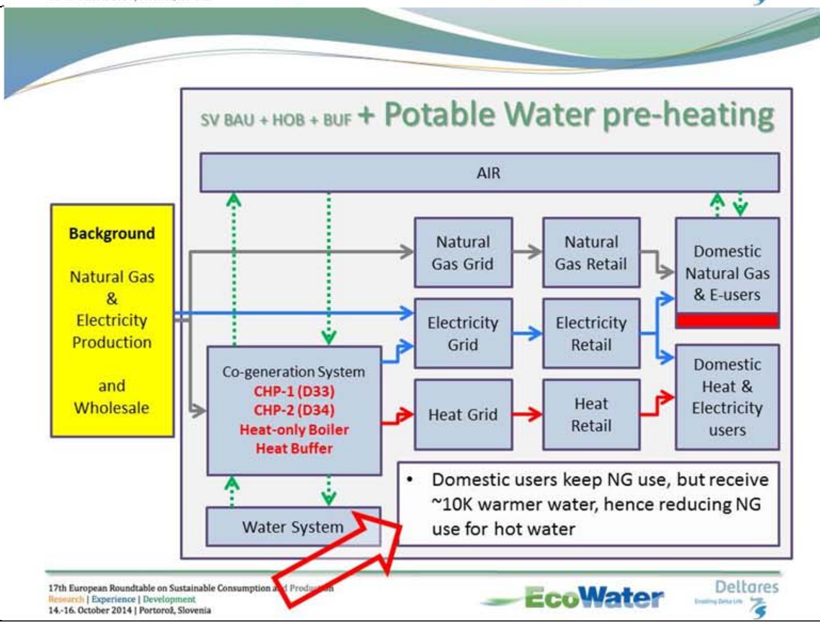
<tr><td></td><td>(19)</td><td>
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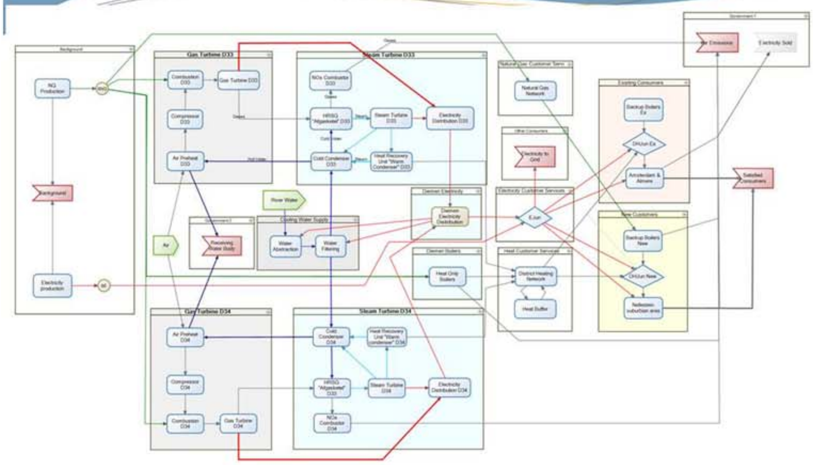

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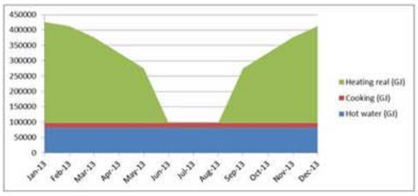
Data

- Operational data are difficult to obtain
  - But: relative results more important than absolute values!
- Investment data are very case dependent, a study in itself
- Temporal dynamics estimation
  - Annual: Estimation on average domestic demands
  - Daily:
    - Baseload heat demand 20%
    - Remaining demand in 8 hours



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Clustering

- Purpose: capture some temporal variation in a stationary model.
- Based on monthly values for heat demand, peak demand and electricity profit on E-wholesale price, clusters are formed

BAU	Number of month/yr (weights in tools)	D33 heat operation (MW)	D34 heat operation (MW)	Electricity sales to grid profit (€/kwh)	E demand	Heat demand
(summer) 1	3	300	Not running	-0,0039	Minimize	Match
2	2	300	900	-0,0005	Minimize	Match
3	2	50	900	0,0013	Maximize	Waste heat
(winter) 4	5	600	900	0,0020	Maximize	Waste heat

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Stakeholders

- Energy and heat
  - producers
  - retailers
- Various levels of government (green ambition, taxes,...)
- Domestic Consumers
- Other consumers (e.g. industry, utility buildings)
  - Only potable water authority included in study

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Preliminary Results

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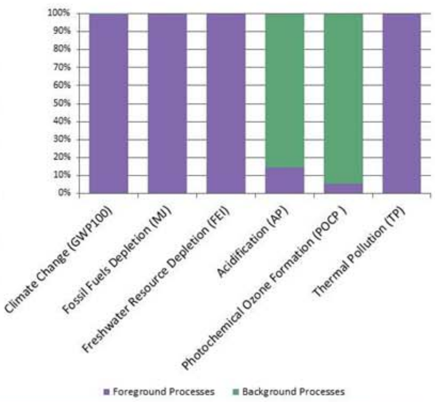
Business as usual – Environmental Pressure

Indicator	Value (Unit)
Climate Change (GWP100)	1.4 $x10^9$
Fossil Fuels Depletion (MJ)	33.4 $x10^9$
Freshwater Resource Depletion (FEI)	22.9 $x10^6$
Acidification (AP)	1.0 $x10^6$
Photochemical Ozone Formation (POCP)	0,14 $x10^6$
Thermal Pollution (TP)	9.5 $x10^6$



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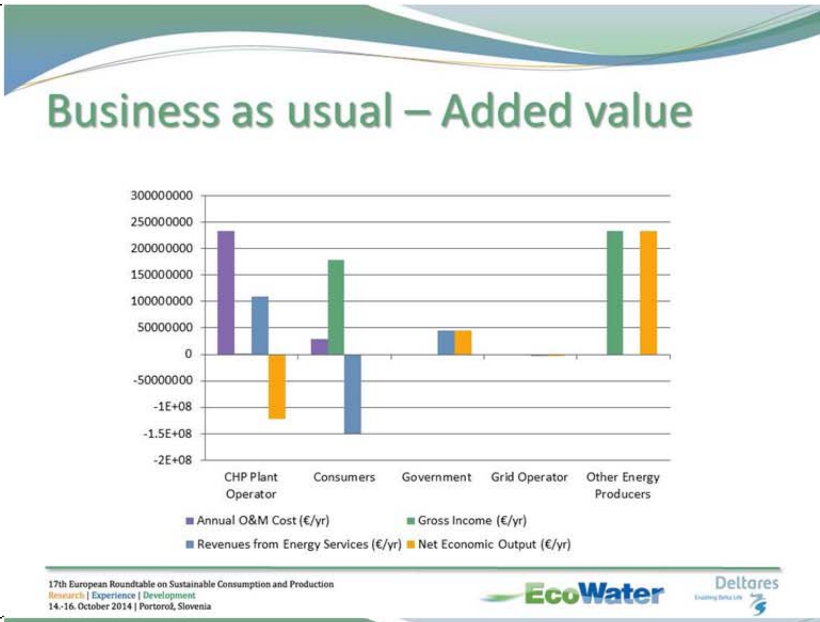
Business as usual – Added value
300000000
250000000
200000000
150000000
100000000
50000000
0
-50000000
-1E+08
-1.5E+08
-2E+08
CHP Plant Operator
Consumers
Government
Grid Operator
Other Energy Producers
Annual O&M Cost (€/yr)
Gross Income (€/yr)
Revenues from Energy Services (€/yr)
Net Economic Output (€/yr)
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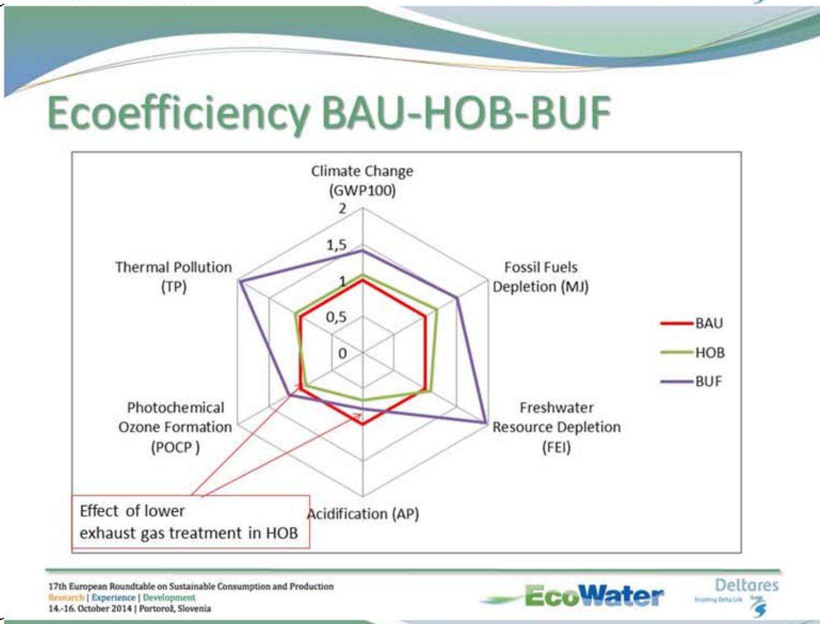
Ecoefficiency BAU-HOB-BUF
Climate Change (GWP100)
2
1,5
1
0,5
0
Fossil Fuels Depletion (MJ)
Freshwater Resource Depletion (FEI)
Acidification (AP)
Photochemical Ozone Formation (POCP)
Thermal Pollution (TP)
BAU
HOB
BUF
Effect of lower exhaust gas treatment in HOB
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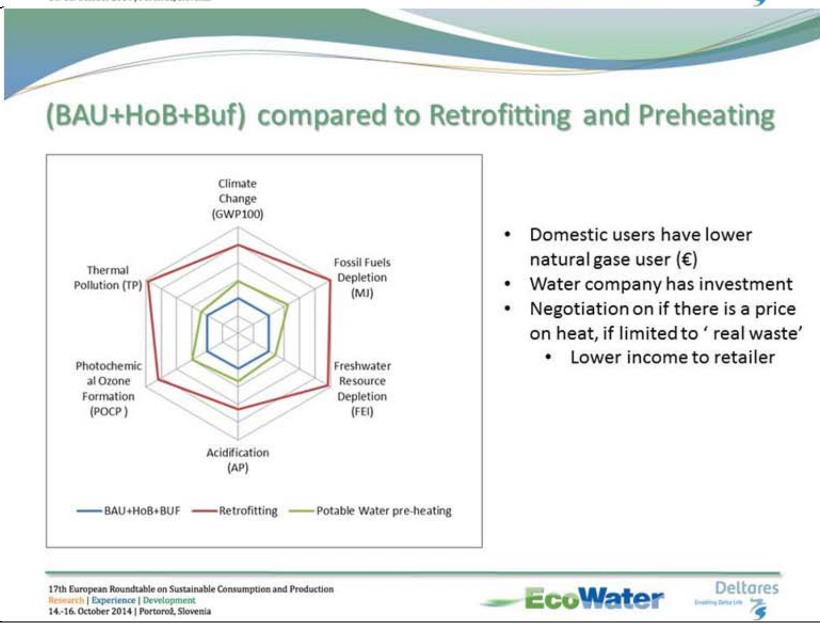
(BAU+HoB+Buf) compared to Retrofitting and Preheating
Climate Change (GWP100)
Fossil Fuels Depletion (MJ)
Freshwater Resource Depletion (FEI)
Acidification (AP)
Photochemic al Ozone Formation (POCP)
Thermal Pollution (TP)
BAU+HoB+BUF
Retrofitting
Potable Water pre-heating
• Domestic users have lower natural gase user (€)
• Water company has investment
• Negotiation on if there is a price on heat, if limited to ' real waste'
• Lower income to retailer
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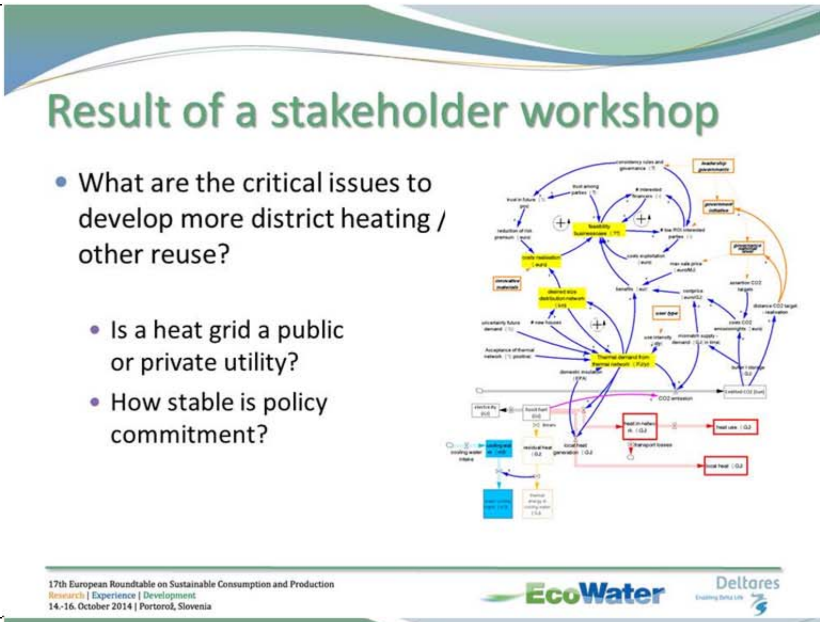
Result of a stakeholder workshop
What are the critical issues to develop more district heating / other reuse?
Is a heat grid a public or private utility?
How stable is policy commitment?
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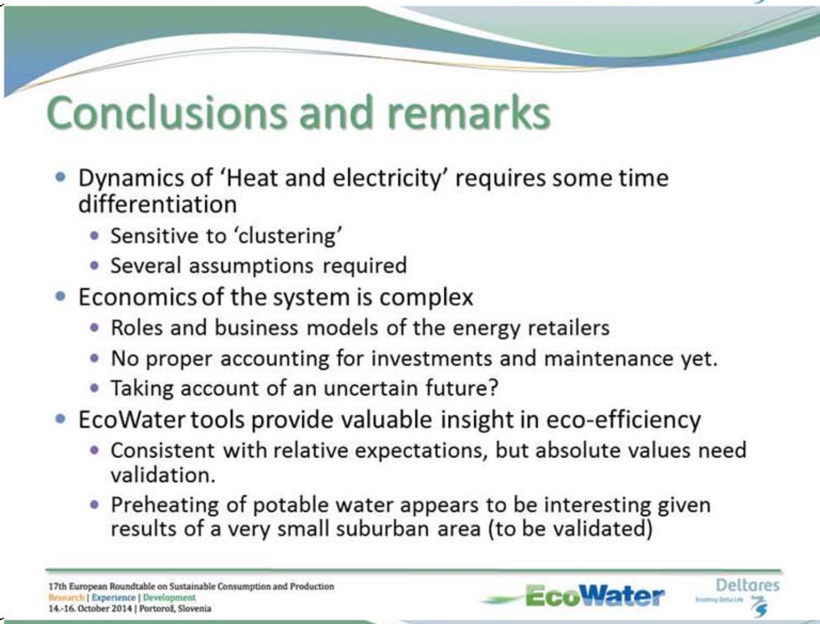
Conclusions and remarks
Dynamics of 'Heat and electricity' requires some time differentiation
Sensitive to 'clustering'
Several assumptions required
Economics of the system is complex
Roles and business models of the energy retailers
No proper accounting for investments and maintenance yet.
Taking account of an uncertain future?
EcoWater tools provide valuable insight in eco-efficiency
Consistent with relative expectations, but absolute values need validation.
Preheating of potable water appears to be interesting given results of a very small suburban area (to be validated)
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Thank you for your attention
For more information, see
http://environ.chemeng.ntua.gr/ecowater
Tuesday 17:10-18:50 – Room 6
"Comparing water footprint methods: the importance of a life cycle approach in assessing water footprint for technology development", L. Danielsson
Wednesday 10:20-12:00 – Room 1
"Value chain upgrading in a textile dyeing industry", A. Balzarini
Wednesday 13:00-14:40 – Room 1
"Towards enhancing whole-system eco-efficiency: case study of a Swiss municipal water system", C. Hugi
"Facilitating multi-stakeholder discussions on improvement options through comparative eco-efficiency assessment", L. Levidow
"Eco-efficiency assessment in the agricultural sector: the Monte Novo irrigation perimeter", R. Maia
"Tools for a systemic approach towards eco-efficiency assessment in water use systems", A. Angelis-Dimakis, NTUA, Greece
Wednesday 15:10-16:50 – Room 1
"Technology options in truck manufacturing: assessing whole-system eco-efficiency", A. Nilsson,
"Technology options in a dairy plant: assessing whole-system eco-efficiency", P. Lindgaard-Jorgensen
EcoWater Workshop
Wednesday 15:10-16:50
Hands-on working session on the EcoWater Tools and Toolbox
17th European Roundtable on Sustainable Consumption and Production
Research | Experience | Development
14.-16. October 2014 | Portorož, Slovenia
EcoWater
Deltares

2.10 Technology options in a dairy plant: assessing whole-system eco-efficiency

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Gert Holm KRISTENSEN

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2.10.1 Abstract

Eco-efficiency assessment is a quantitative management tool, which enables the study of life-cycle environmental impacts of a product system along with its economic value for stakeholders involved in a water value chain- from abstraction to end use (ISO 14045). The FP7 EcoWater Project has developed guidance material and tools for analysing the eco-efficiency of water-service systems. The whole-system analysis includes environmental assessments of the product system, its economic value and its quantitative eco-efficiency along water value chains with different actors (water providers, water users and Waste Water treatment companies). This case study uses the EcoWater tools in investigating options for whole-system eco-efficiency improvement a dairy plant producing milk powder and other upgraded milk fractions. The study focused on a production site in Holstebro, Denmark, which use water in its utility operation and in the process for cleaning (Cleaning in Place, CIP), rinse processes and standardization of products. The dairy has a strong environmental strategy aiming at reducing resource burdens, especially greenhouse gas emissions and water use. It strives to identify technologies which are cost-effective in reducing resource burdens both within their own production system and in the water value chain. The dairy plant has full management control of the dairy production stage and partly of the transport system through contracts with transport companies. For the other stages, different actors control the pricing of services and investment decisions for new technologies and in management and operation.

In this study the water value chain is modelled in five stages: water supply, dairy production, wastewater treatment, energy production (biogas) and transport. The study assessed how several technology options would change the whole-system eco-efficiency, i.e. a ratio between total value added (TVA) and resource burdens. The later were assessed through standard mid-point indicators (JRC, 2011). Data came from the companies and from LCI databases. According to the results, all technology options would lower the whole-system resource use and environmental impacts, varying from minimal to significant improvements. Some technologies would improve the overall system resource use and reduce the environmental impact but would require larger investment costs, especially in the dairy production stage. So those options would lower the whole-system eco-efficiency.

A few technology options would improve the whole-system TVA, resulting

from a greater TVA for the dairy operation stage. but would reduce TVA for the water supply and wastewater operators. Combining actor investment in technologies in all three stages (water supply, wastewater treatment and dairy production) may provide new opportunities to both reduce the impact and optimise the TVA for more actors in the water value chain. The modelling analyses provided a basis for workshops with the actors in the value chain to discuss how to optimize whole-system eco-efficiency and how to anticipate distributional effects. The workshops also drew on the PESTLE-scenario method to discuss drivers and barriers of such eco-innovations, how those factors may change in the future, and how companies could anticipate or influence those changes. The results show how multi-stakeholder discussion can benefit eco-efficiency comparisons and selection of the best technologies from a technological, economic and environmental performance perspective.

Keywords
Resource efficiency, supply and value chain optimization, cleaner production, sustainability

References

EcoWater Project website: http://environ.chemeng.ntua.gr/EcoWater

ISO (2012). Environmental management – Eco-efficiency assessment of product systems – Principles, requirements and guidelines, ISO 14045:2012. International Organization for Standardization, CEN.

Jasch, C. (2009). Environmental and Material Flow Cost Accounting - Principles and Procedures, (Eco-efficiency in Industry and Science, Vol. 25). New York: Springer.

JRC (2011). European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference Life Cycle Data system (ILCD) Handbook – General Guide for Life Cycle Assessment – Detailed guidance. First edition. Luxembourg: Publication Office of the European Union.

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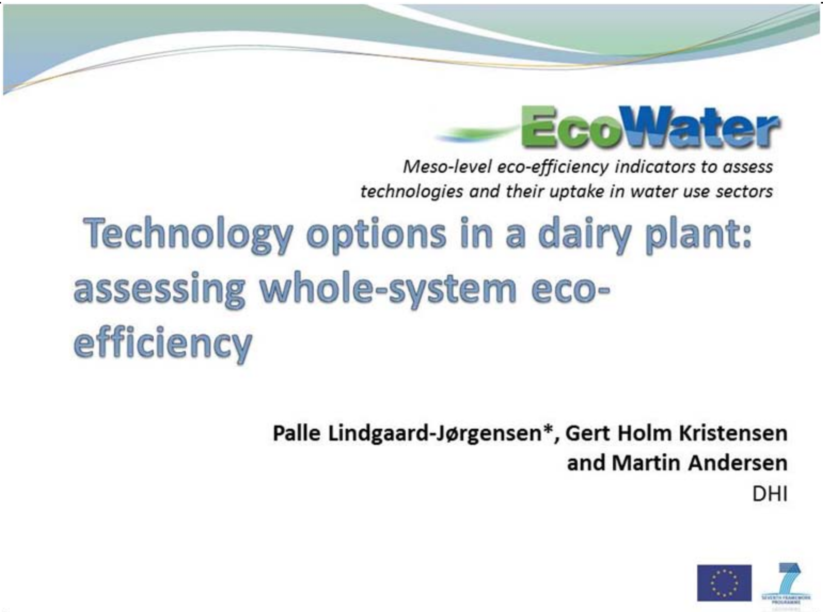
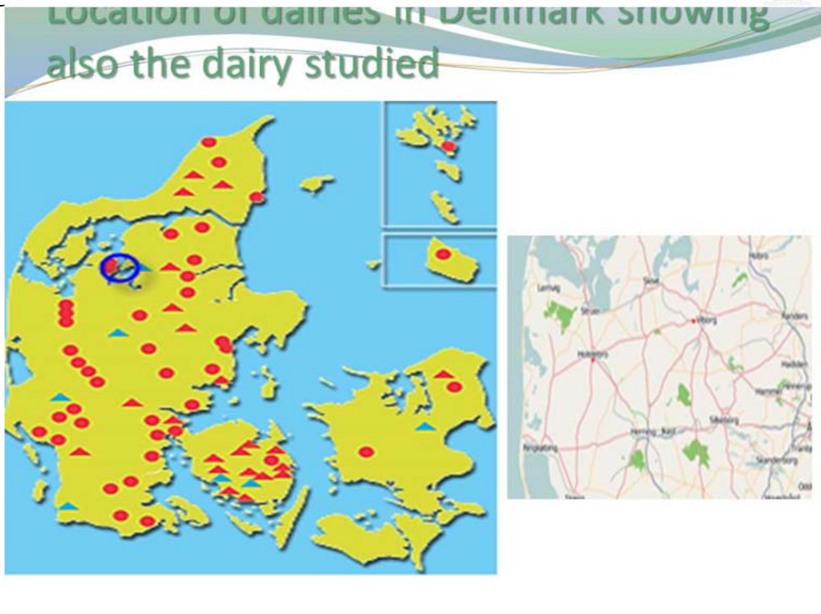
2.10.2 Presentation

(1)	
(2)	

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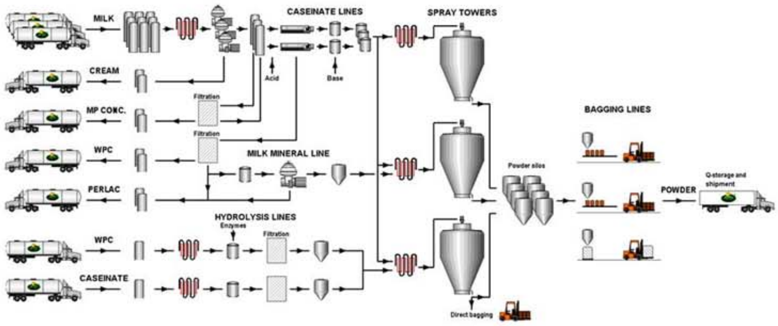
HOCO's production- Milk Powder



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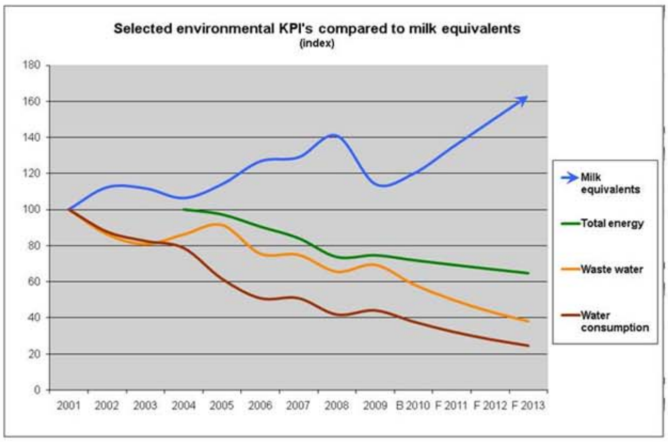
Environmental KPI's- dairy progress



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System overview and boundaries- looking also outside of the dairy

Five stages:

- Water Supply Operator: Vestforsyning Water
- Dairy Industry: HOCO
- Wastewater Treatment Operator: Vestforsyning Wastewater
- Energy Production Plant: Maabjerg Bioenergy Plant
- Transport: Private transportation companies

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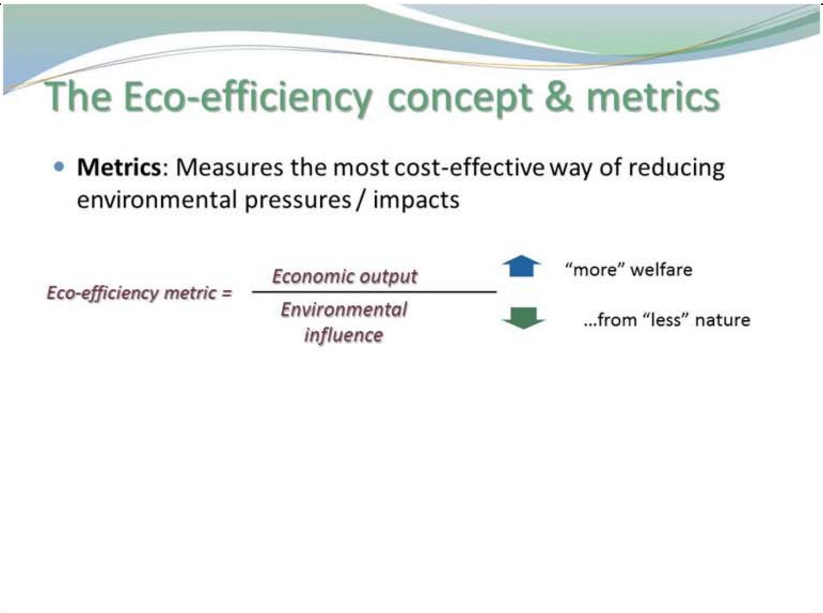
The Eco-efficiency concept & metrics
Metrics: Measures the most cost-effective way of reducing environmental pressures / impacts
Eco-efficiency metric =
Economic output
Environmental influence
"more" welfare
...from "less" nature

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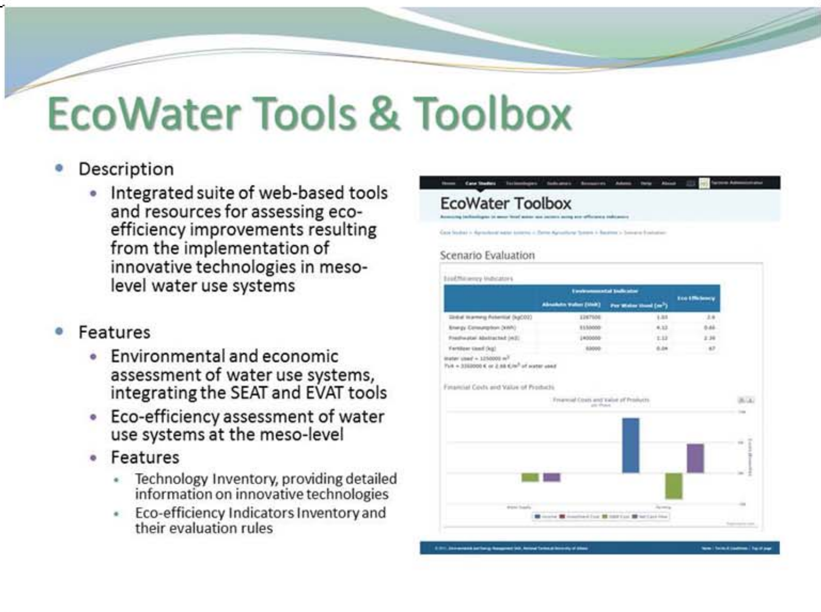
EcoWater Tools & Toolbox
Description
Integrated suite of web-based tools and resources for assessing eco-efficiency improvements resulting from the implementation of innovative technologies in meso-level water use systems
Features
Environmental and economic assessment of water use systems, integrating the SEAT and EVAT tools
Eco-efficiency assessment of water use systems at the meso-level
Features
Technology Inventory, providing detailed information on innovative technologies
Eco-efficiency Indicators Inventory and their evaluation rules
EcoWater Toolbox
Scenario Evaluation

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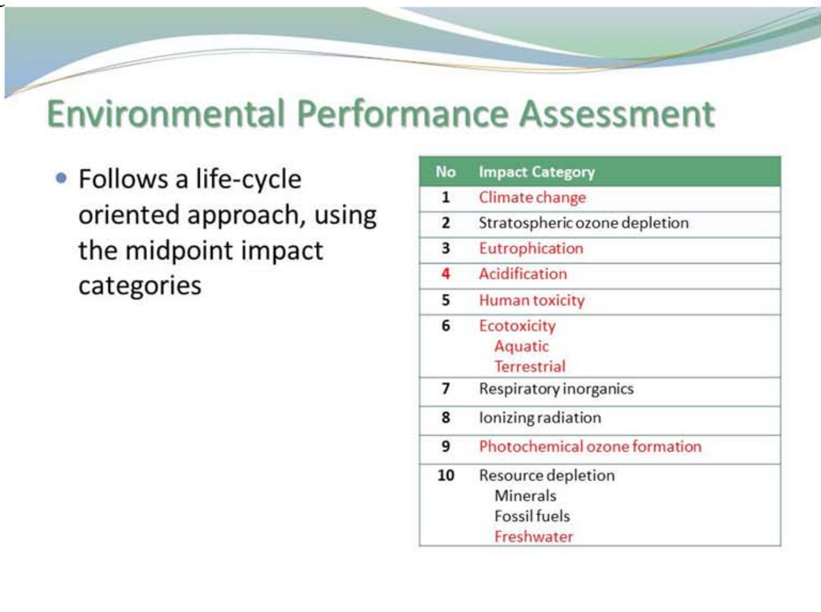
Environmental Performance Assessment
Follows a life-cycle oriented approach, using the midpoint impact categories
No
Impact Category
1 Climate change
2 Stratospheric ozone depletion
3 Eutrophication
4 Acidification
5 Human toxicity
6 Ecotoxicity
Aquatic
Terrestrial
7 Respiratory inorganics
8 Ionizing radiation
9 Photochemical ozone formation
10 Resource depletion
Minerals
Fossil fuels
Freshwater

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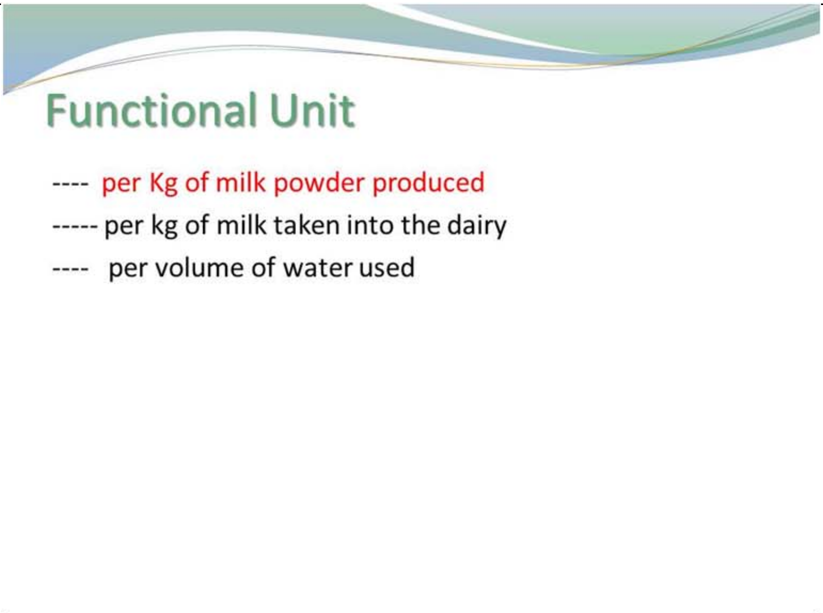

Functional Unit
---- per Kg of milk powder produced
----- per kg of milk taken into the dairy
---- per volume of water used

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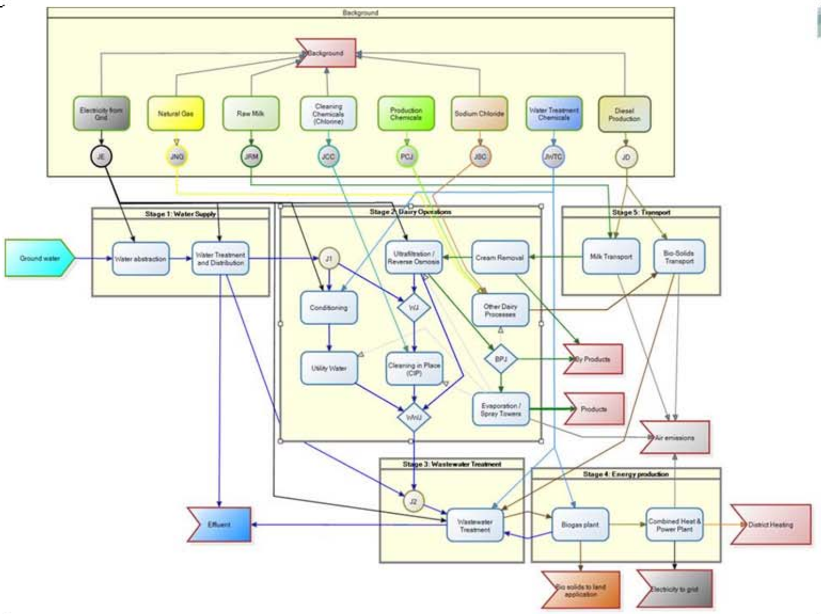

Background
Ground water
Water abstraction
Water Treatment and Distribution
Cream Removal
Milk Transport
Conditioning
Utility Water
By Products
Products
Air emissions
Effluent
Wastewater Treatment
Biogas plant
Combined Heat & Power Plant
District Heating

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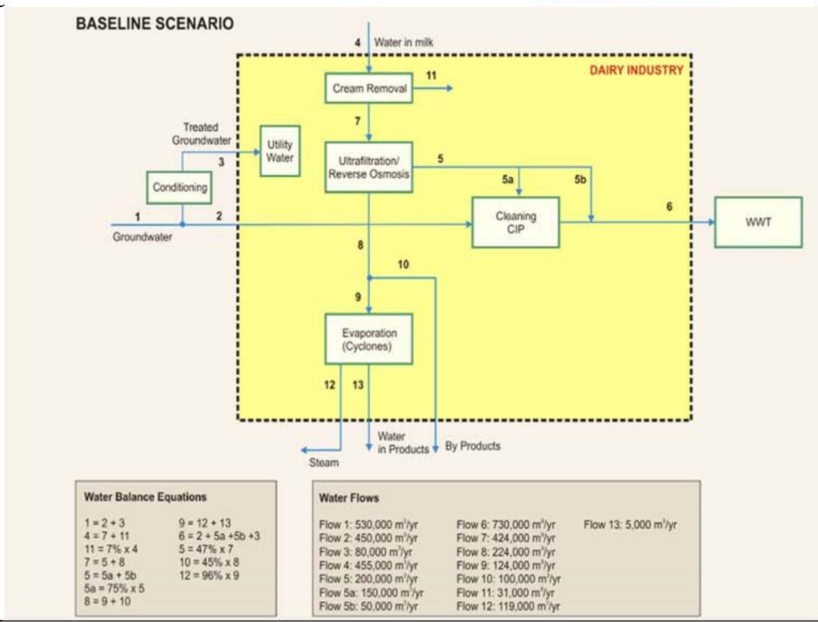

BASELINE SCENARIO
4 Water in milk
DAIRY INDUSTRY
Cream Removal
11
7
Treated Groundwater
Utility Water
3
Ultrafiltration/ Reverse Osmosis
5
5a
5b
Conditioning
1
2
Groundwater
Cleaning CIP
6
WWT
8
10
9
Evaporation (Cyclones)
12
13
Steam
Water in Products
By Products
Water Balance Equations
1 = 2 + 3
4 = 7 + 11
11 = 7% x 4
7 = 5 + 8
5 = 5a + 5b
5a = 75% x 5
8 = 9 + 10
9 = 12 + 13
6 = 2 + 5a +5b +3
5 = 47% x 7
10 = 45% x 8
12 = 96% x 9
Water Flows
Flow 1: 530,000 m³/yr
Flow 2: 450,000 m³/yr
Flow 3: 80,000 m³/yr
Flow 4: 455,000 m³/yr
Flow 5: 200,000 m³/yr
Flow 5a: 150,000 m³/yr
Flow 5b: 50,000 m³/yr
Flow 6: 730,000 m³/yr
Flow 7: 424,000 m³/yr
Flow 8: 224,000 m³/yr
Flow 9: 124,000 m³/yr
Flow 10: 100,000 m³/yr
Flow 11: 31,000 m³/yr
Flow 12: 119,000 m³/yr
Flow 13: 5,000 m³/yr

(12)

Baseline Environmental Performance

Midpoint Impact Category	Environmental Performance Indicator per kg of milk powder produced	Foreground Contribution	Background Contribution
Climate change	64 $kgCO_{2eq}$/ kg	45	55
Freshwater Resource Depletion	8.6 m^3/kg	100	0
Eutrophication	1,7 $kgPO_4^{3-}{}_{,eq}$/kg	0,3	99,7
Human toxicity	1,05 $kg1,4DCB_{,eq}$/kg	14	86
Acidification	0.06 $kgSO_2^{-}{}_{,eq}$/kg	0,8	99,2
Aquatic Ecotoxicity	0,002 $kg1,4DCB_{,eq}$/kg	0	100
Terrestrial Ecotoxicity	0,003	0	100

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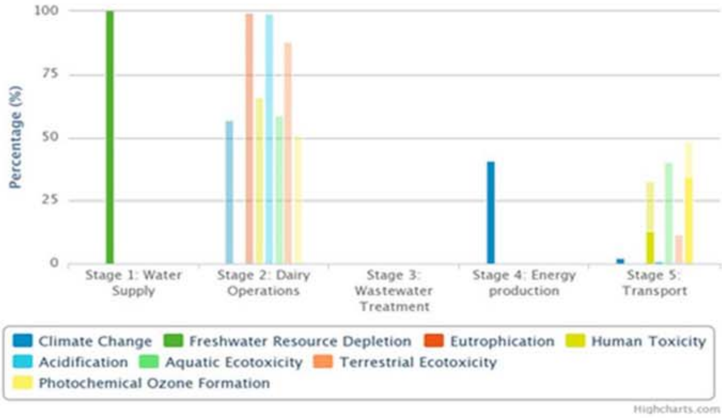
Performance per stage



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Economic evaluation of the Baseline total 30 million (€/yr)

Actor	Annual O&M costs (€/yr)	Gross income (€/yr)	Revenues from services €/yr)	Net economic output €/yr)
Water supply operator	52.731	0	953.300	882.569
Dairy industry	213.154.418	249.642.370	-9.668.941	26.819.011
WWT operator	294.049	0	2.428.019	2.133.970
Biogas plant	19.618	102.627	0	83.008
Transport companies	6.022.515	0	6.305.620	283.105

(15)

Baseline eco-efficiency

Midpoint Impact Category	Unit	Total for the value chain
Climate change	€/kgCO_{2eq}	30
Freshwater Resource Depletion	€/m^3	202
Eutrophication	€/kg$PO_4{}^{3}{}_{-,eq}$	0.99
Human toxicity	€/kg1,4$DCB_{,eq}$	28,5
Acidification	€/kg$SO^{2-}{}_{,eq}$	3,14
Aquatic Ecotoxicity	€/kg1,4$DCB_{,eq}$	737
Terrestrial Ecotoxicity	€/kg1,4$DCB_{,eq}$	630
Photochemical Ozone Formation	€/kg $C_2H_{4,eq}$	3271

(16)

Technologies to upgrade the value chain

Technology Scenario	Technologies Included
Resource Efficiency	Anaerobic pre-treatment of dairy waste water
	Increasing the efficiency of the Cleaning in Place operation
	Condensation of water vapour from drying of milk powder
Pollution Prevention	Anaerobic pre-treatment of dairy waste water
Circular economy	Advanced oxidation and UV treatment

(17)

Net economic output all the involved actors and the total valued added of the system

Net Economic Output	Baseline	Anaerobic Pre-treatment	Advanced oxidation and UV treatment	Combined technologies scenario 5	Combined technolo-gies scenario 6 and more efficient blowers
Water supply operator	882.569	0%	-54%	-54%	-50%
Dairy	26.819.011	+9%	+10%	+11%	+10%
WWT operator	2.133.970	+2%	-40%	-40%	-42%
Biogas plant	83.008	-25%	-17%	-18%	-20%
Transport company	283.105	0%	0%	0%	0%
Total	30.202.000	+8%	+4%	+4%	+4%

(18)

Eco-efficiency of implementing technologies

Midpoint Impact Category	Base line	1. Anaero-bic pretreat-ment	2. Advanced oxication UV light treatment	3 Upgrading CIP	4 Reuse of conden- sate from drying of product	5 More efficient blowers – diffusors
Climate change	30 €/kgCO_{2eq}	+10%	+6,8%	+0,8%	0%	+1%
Fresh-water Resource Depletion	202 €/m³	+0%	+55%	+7%	+ 20%	0%
Eutrophi-cation	0,99 €/kg$PO_4^{3-}{}_{,eq}$	0%	+8%	+4%	+4%	0%
Human toxicity	28,5 €/kg1,4DCB$_{,eq}$	+9%	0%	+6%	+6%	+2%
Acidifica-tion	3,1 €/kg$SO^{2-}{}_{,eq}$	+9%	+2%	+6%	+6%	0%
Aquatic Eco-toxicity	737 €/kg1,4DCB$_{,eq}$	+8%	+1%	+6%	+2%	0%
Terres-trial Eco-toxicity	630 €/kg1,4DCB$_{,eq}$	+8%	+2%	+7%	+7%	0%
Photochemical Ozone Forma-tion	3271 €/kg $C_2H_{4,eq}$	+8%	+1%	+8%	+8%	0%

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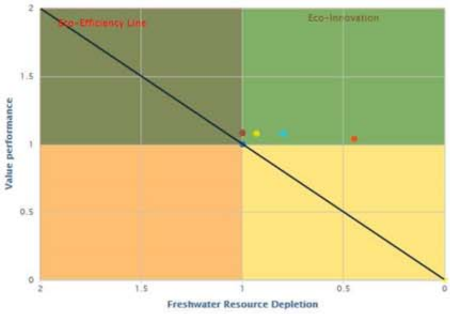
Improving both value and environmental impact



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Conclusions I

- The analysis of the baseline situation in the water value chain provided insight into the value created in the value chain, to the environmental performance and to the weak points in the value chain which had the lowest eco-efficiencies.
- Technologies could be identified which were able to increase the eco-efficiency of the weak points in the value chain.
- Anaerobic pre-treatment, advanced oxidation in the and more efficient blowers in the waste water treatment plant showed the highest improvements of eco-efficiency for climate change and water resources depletion.

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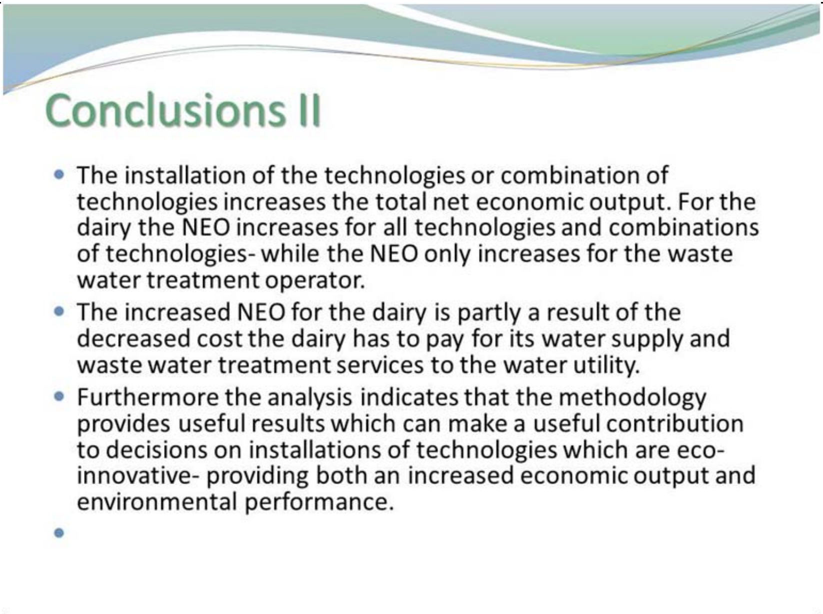
Conclusions II
The installation of the technologies or combination of technologies increases the total net economic output. For the dairy the NEO increases for all technologies and combinations of technologies- while the NEO only increases for the waste water treatment operator.
The increased NEO for the dairy is partly a result of the decreased cost the dairy has to pay for its water supply and waste water treatment services to the water utility.
Furthermore the analysis indicates that the methodology provides useful results which can make a useful contribution to decisions on installations of technologies which are eco-innovative- providing both an increased economic output and environmental performance.

2.11 Technology options in truck manufacturing: assessing whole-system eco-efficiency

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[2] Open University

2.11.1 Abstract

Eco-innovation has been generally directed at energy input-substitutes, end-of-pipe emissions control, component recycling, etc. Some companies have made investments reducing resource burdens within the production process. Such eco-innovations aim to combine economic advantage with lower resource burdens. These improvements have been often assessed (and compared) as an eco-efficiency ratio within a production unit. Looking further, the FP7 EcoWater project has analysed eco-efficiency on a whole-system level, i.e. among heterogeneous actors across the water value chain (process-water users, providers and WWT companies).

Along those lines, this study investigated technology options for whole-system eco-efficiency improvement in truck-cabin production at Volvo Trucks, which is serviced by companies for water abstraction and wastewater treatment. The study focused on two production sites, Umeå and Tuve, which use water in corrosion-protection processes. Relative to its overall industrial sector, Volvo represents strong prospects for reducing resource burdens in water-use processes, especially from chemical inputs and wastewater. Such eco-innovations involve more complex interactions beyond the production site, so the options warrant a whole-system comparative assessment, whose flows are shown in the Figure.

A modelling study assessed how different technology options would change the whole-system eco-efficiency, i.e. a ratio between total value added (TVA) and resource burdens. The later were assessed through standard mid-point indicators (JRC, 2011). Data came from the companies and from literature. The results are not conclusive across the set of environmental indicators, i.e. they show both environmental improvement and impairment within the same technology evaluation. Some technology options improve whole-system eco-efficiency, but some offer only minimal improvements or impairment.

The results show options where the TVA would be redistributed across the whole-system value chain: the Tuve site would pay the water-supply company for less water and would pay the WWT company Stena for much less WW to treat. But for the system the TVA still increases.

The analyses provided a basis for two multi-stakeholder workshops to discuss

how to optimize whole-system eco-efficiency and how to anticipate distributional effects. The workshops also drew on the PESTLE-scenario method to discuss drivers and barriers of such eco-innovations, how those factors may change in the future, and how companies could anticipate or influence such changes. The wastewater treatment company stressed the importance of stakeholder collaboration at an early stage of technology changes in industry. Discussions in the pre-implementation planning would highlight e.g. whether potential changes in waste and wastewater composition render a higher treatment service price. The methodology and tools developed in EcoWater can be very helpful in such discussions.

The results show how multi-stakeholder discussion can benefit eco-efficiency comparisons, the scenario method and company strategies. This paper will also evaluate the methods, as applied in an industrial context, and discuss possible improvements.

Reference

JRC (2011). European Commission – Joint Research Centre – Institute for Environment and Sustainability: International Reference - Life Cycle Data system (ILCD) Handbook – General Guide for Life Cycle Assessment – Detailed guidance. First edition. Luxembourg: Publication Office of the European Union.

Keywords

Eco-efficiency, resource efficiency, stakeholder interaction, systems analysis, scenario development

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2.11.2 Presentation

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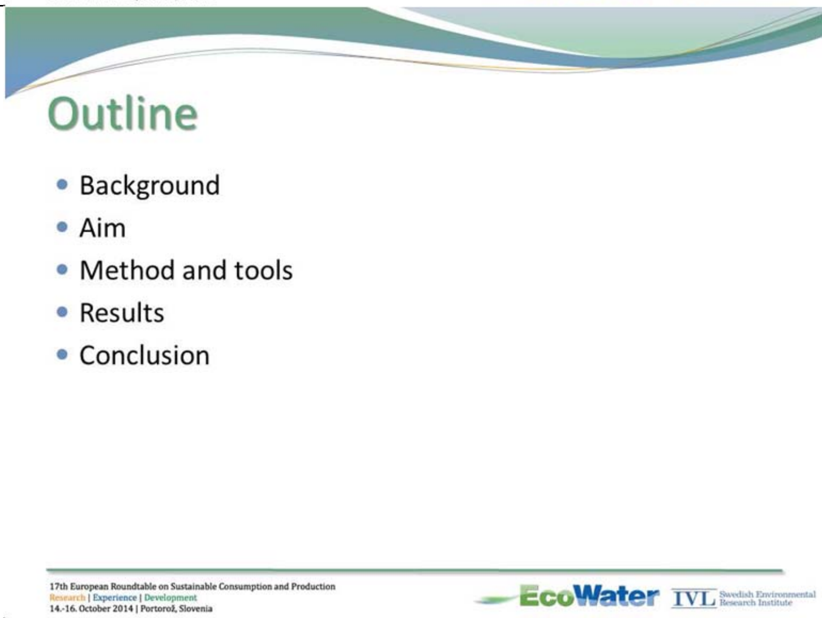

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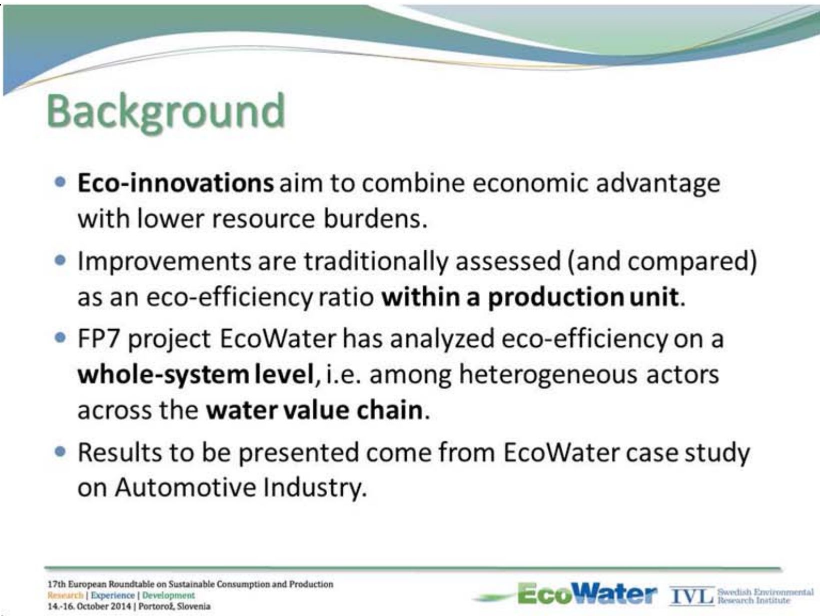
Background
Eco-innovations aim to combine economic advantage with lower resource burdens.
Improvements are traditionally assessed (and compared) as an eco-efficiency ratio within a production unit.
FP7 project EcoWater has analyzed eco-efficiency on a whole-system level, i.e. among heterogeneous actors across the water value chain.
Results to be presented come from EcoWater case study on Automotive Industry.
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IVL Swedish Environmental Research Institute

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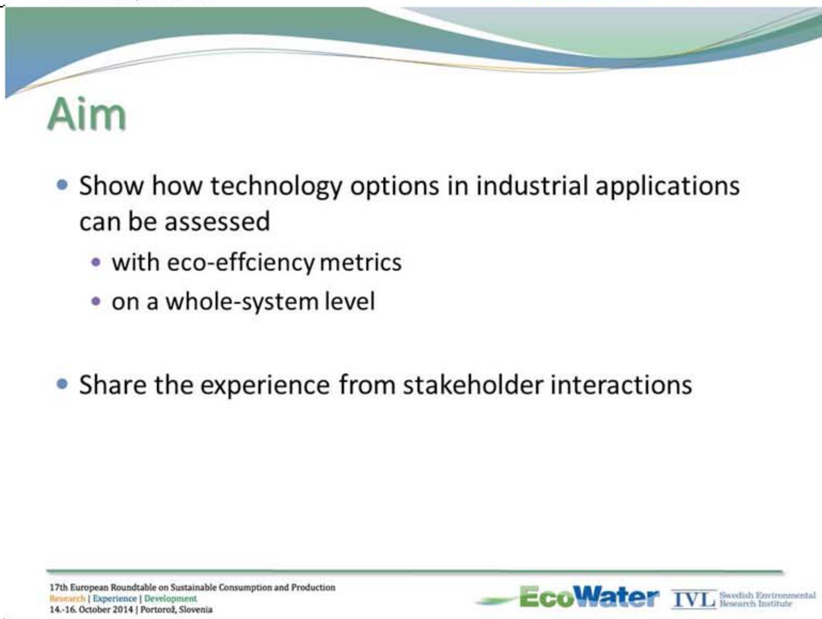
Aim
Show how technology options in industrial applications can be assessed
with eco-effciency metrics
on a whole-system level
Share the experience from stakeholder interactions
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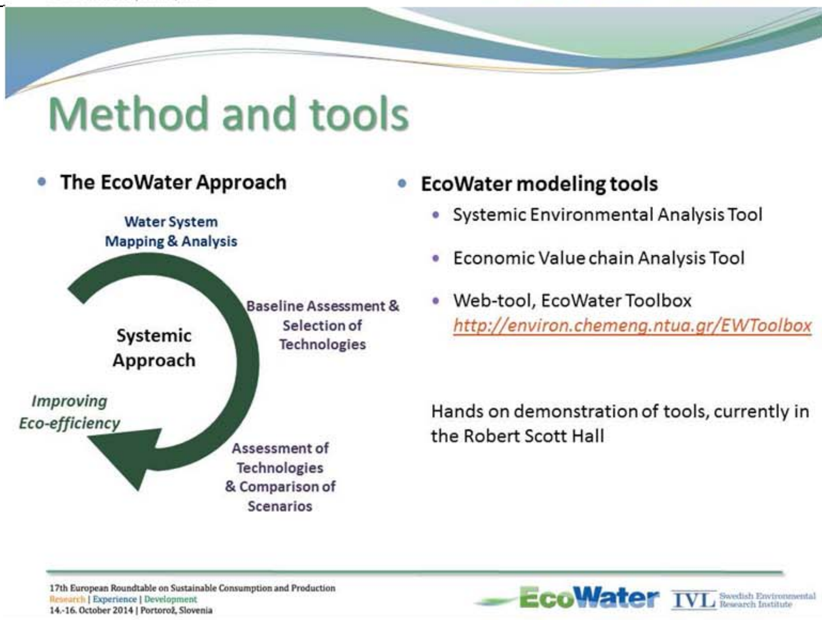
Method and tools
The EcoWater Approach
Water System Mapping & Analysis
Baseline Assessment & Selection of Technologies
Systemic Approach
Improving Eco-efficiency
Assessment of Technologies & Comparison of Scenarios
EcoWater modeling tools
Systemic Environmental Analysis Tool
Economic Value chain Analysis Tool
Web-tool, EcoWater Toolbox
http://environ.chemeng.ntua.gr/EWToolbox
Hands on demonstration of tools, currently in the Robert Scott Hall
17th European Roundtable on Sustainable Consumption and Production
Research | Experience | Development
14.-16. October 2014 | Portorož, Slovenia
EcoWater
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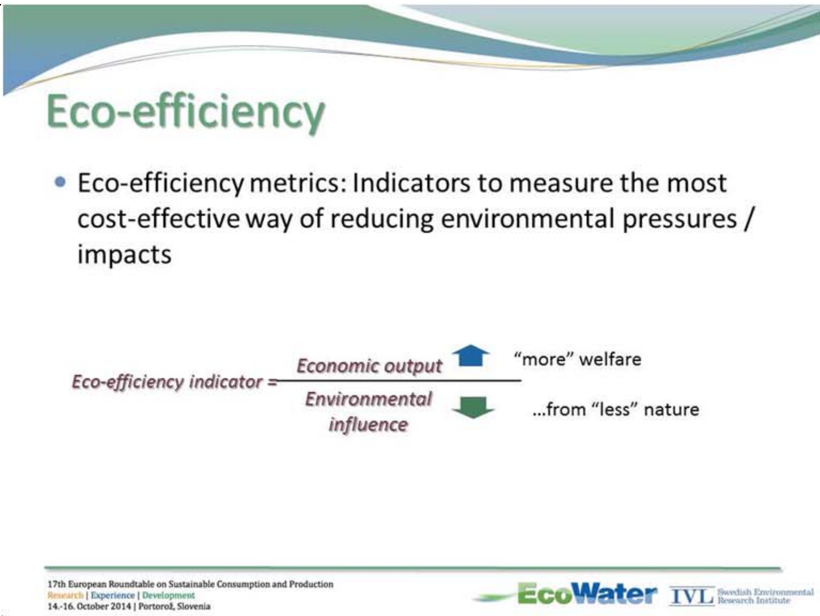
<tr><td>(6)</td><td></td><td>
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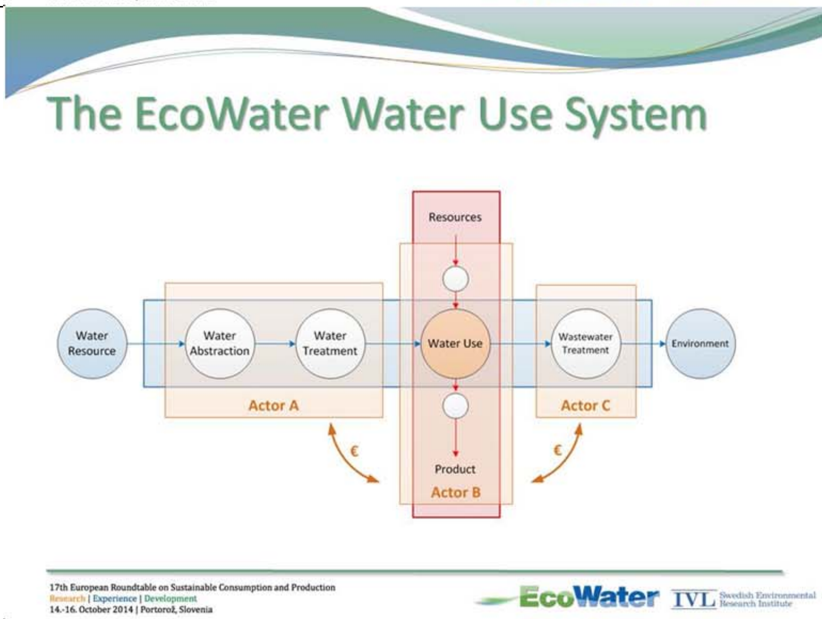
<tr><td>(7)</td><td></td><td>
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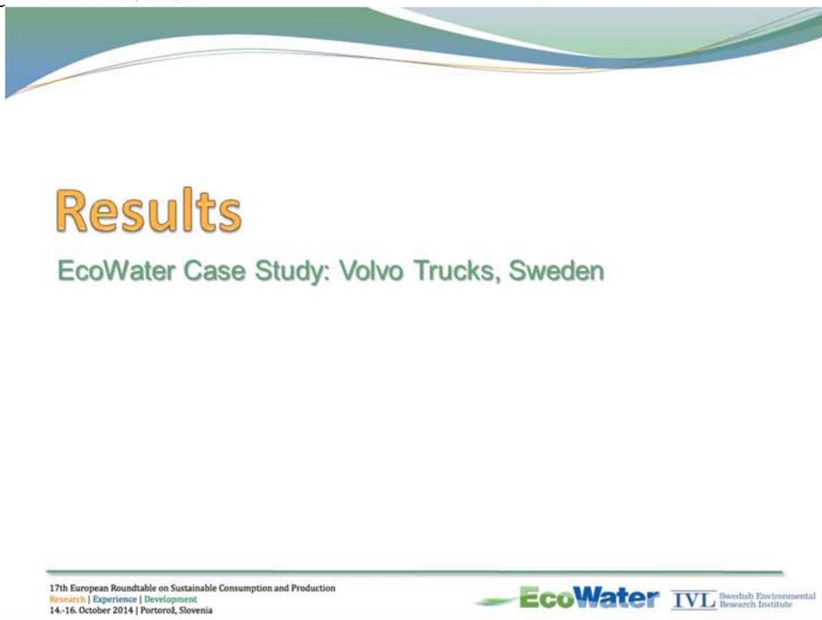
<tr><td>(8)</td><td></td><td>
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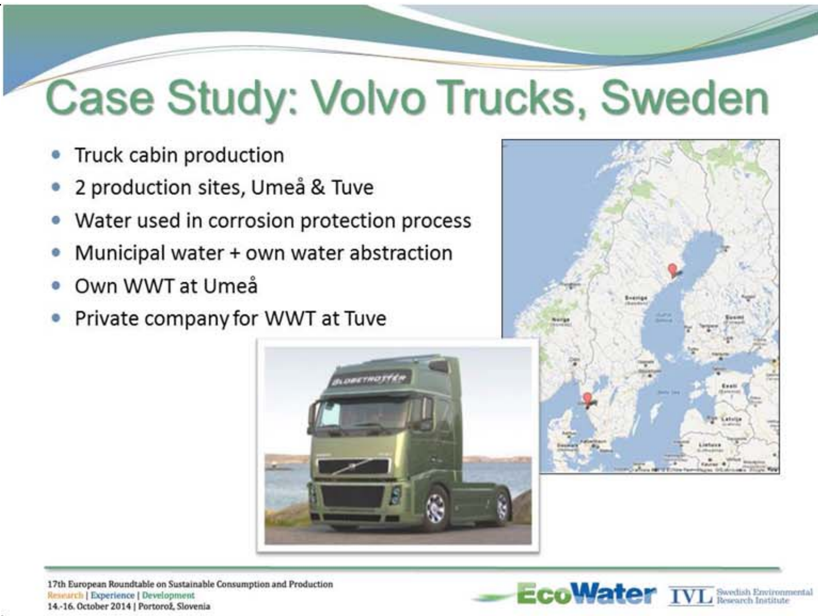
<tr><td>(9)</td><td>
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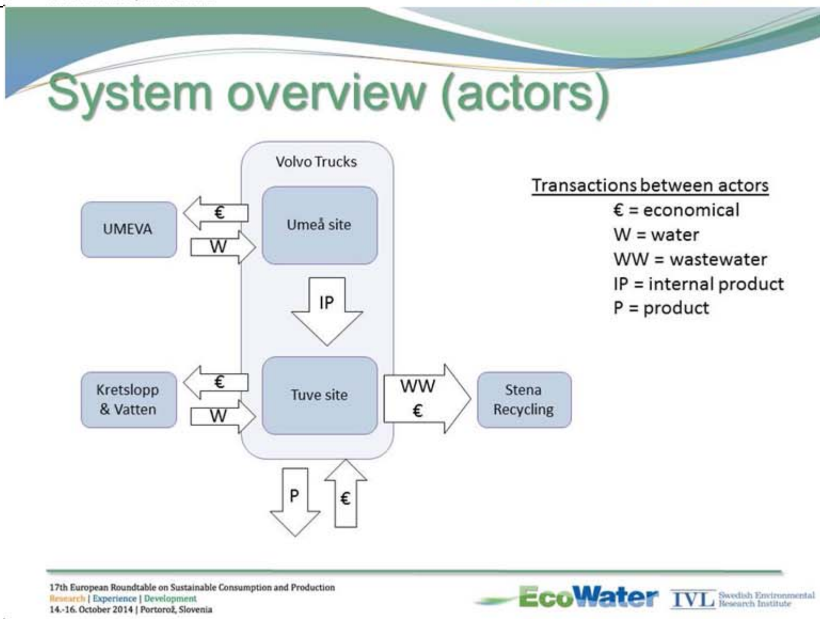
<tr><td>(10)</td><td>
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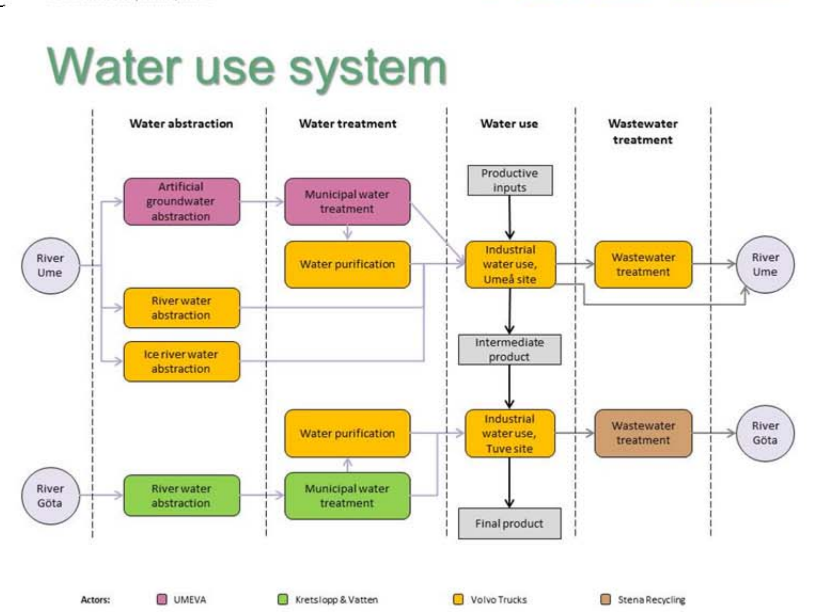
<tr><td>(11)</td><td>
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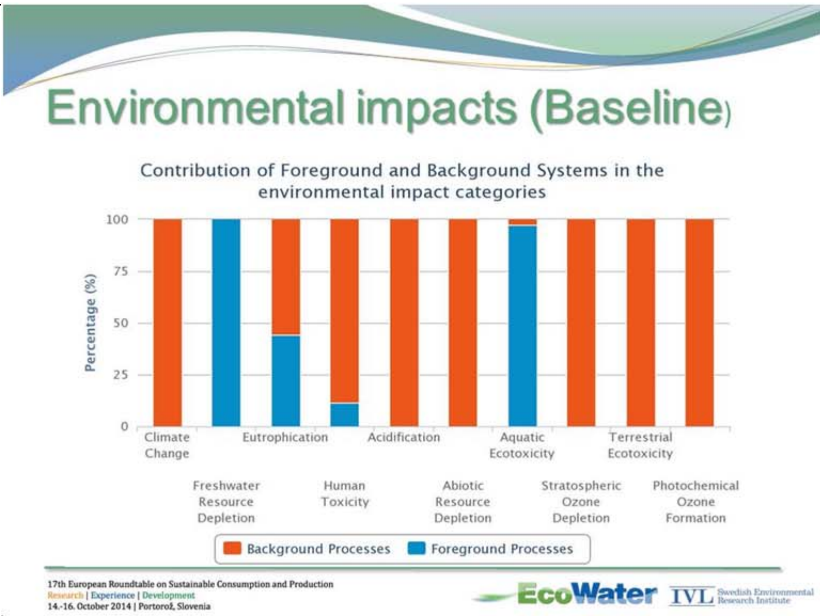

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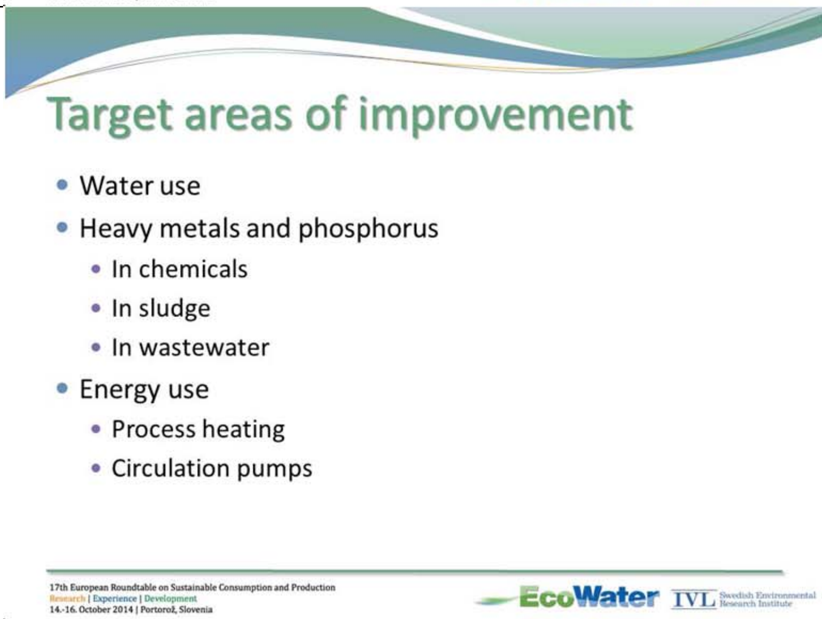

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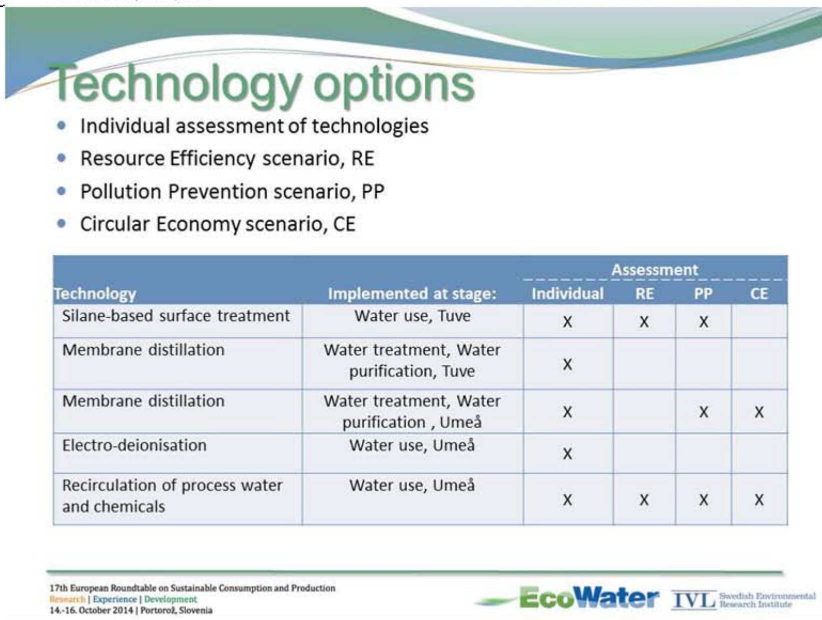

Technology	Implemented at stage:	Assessment: Individual	RE	PP	CE
Silane-based surface treatment	Water use, Tuve	X	X	X	
Membrane distillation	Water treatment, Water purification, Tuve	X			
Membrane distillation	Water treatment, Water purification , Umeå	X		X	X
Electro-deionisation	Water use, Umeå	X			
Recirculation of process water and chemicals	Water use, Umeå	X	X	X	X

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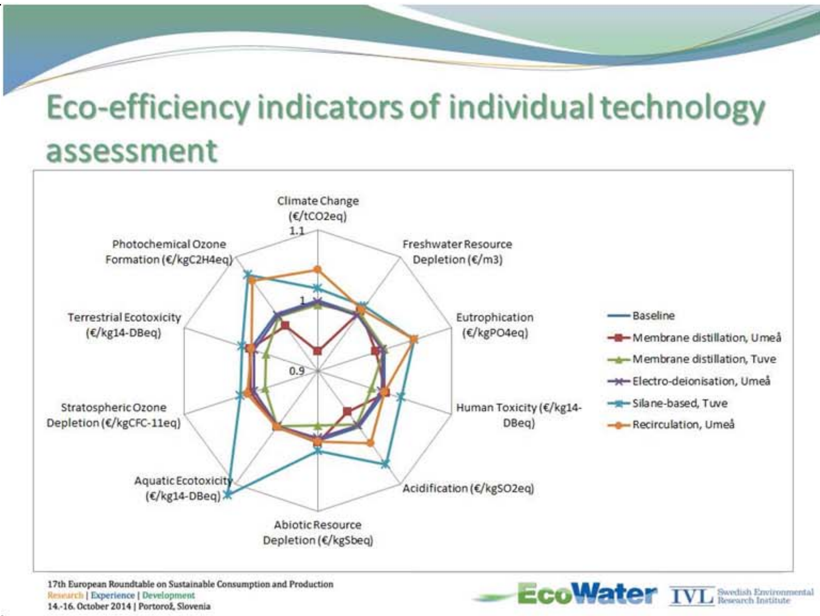

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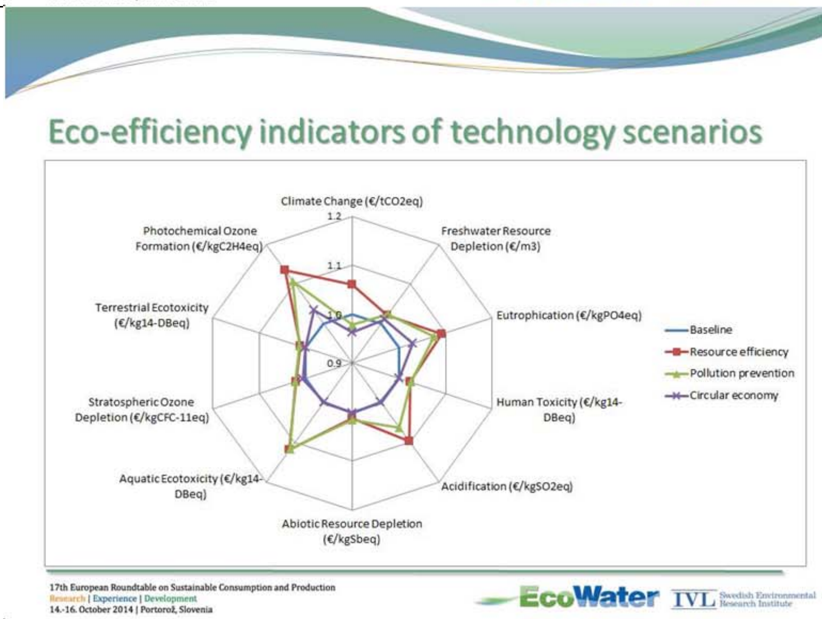

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Economic performance

Change in Total Value Added and Net economic output per actor (€)

	TVA	UMEVA	Kretslopp och Vatten	Volvo Trucks	Stena Recycling
Baseline	~ 28 900 000	~ 20 000	~ 2 100	~ 28 700 000	~ 160 000
Technology scenario assessments					
Resource efficiency	+	=	-	+	-
Pollution prevention	-	-	-	+	-
Circular economy	-	-	=	-	=
Individual technology assessments					
Silane-based, Tuve	+	=	-	+	-
Membrane distillation, Tuve	-	=	-	-	=
Membrane distillation, Umeå	-	-	=	-	=
Electro-deionisation, Umeå	-	=	=	-	=
Recirculation, Umeå	-	=	=	-	=

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(18)	**Stakeholder interactions**
	• Workshops to gather system stakeholders were held on two occasions
	• Purpose
	  • Create a dialog between the EcoWater project participants and the actors/stakeholders of the Volvo Trucks water value chain.
	  • Discuss results of technology eco-efficiency assessment.
	  • Bring stakeholders of the system together to promote fruitful interaction.
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(19)	**Outcome of workshops**
	• The results of technology eco-efficiency assessment triggered discussions between stakeholders.
	• The systemic view brought greater insight for stakeholder into
	  • where the largest environmental and/or economical improvements can be made
	  • that technology implementation could redistribute the economic outcome of the system
	  • how stakeholders may influence each other within a common water use system
	"We are interested in ***early information*** *from Volvo when they do test runs of new technology and to get samples of wastewater. It is of importance that Stena Recycling gets to know* ***what kind of wastewater to expect*** *from Volvo, so we can plan for this well in advance before it happens. Depending on the change in composition it* ***could affect the cost*** *for treatment."*
	Christina Öjersson, Stena Recycling
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(20)	**Conclusion**
	• The EcoWater methodology provides a straightforward step-by-step framework on conducting eco-efficiency analysis of technology options in industrial applications.
	• Difficulties lay in finding sufficiently accurate data on
	  • the industrial process
	  • new technologies
	  • background processes via Open Access LCA
	• Good communication with the stakeholders will speed up and enhance the result of the modelling work.
	• The systemic eco-efficiency assessments can stimulate stakeholder interactions and discussions, which lead to stronger relations.
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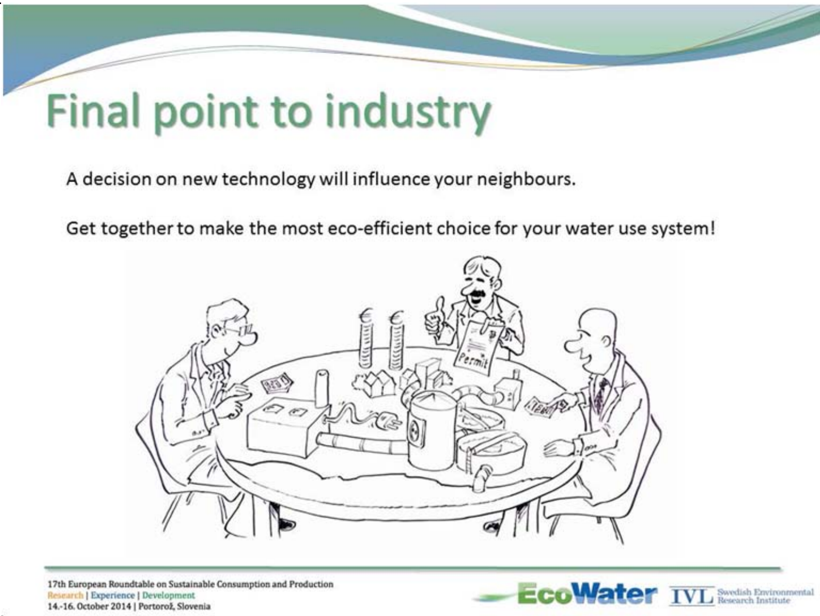
<tr><td>(21)</td><td>
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2.12 Comparing water footprint methods: the importance of a life cycle approach in assessing water footprint

Sara ALONGI SKENHALL[1], Lina DANIELSSON[1] and Tomas RYDBERG[1]

[1] IVL Swedish Environmental Research Institute, Sweden

2.12.1 Abstract

Water footprint (WFP) was introduced as an indicator for freshwater use in 2002. Since then, many methods have been developed to calculate volume of freshwater consumed during production, including both water use and degradation (pollution).

This study applied a selection of WFP methods in a case study on water using processes in truck production at Volvo Trucks, Sweden. This case study is a part of the FP7 project EcoWater that focuses on environmental impacts from water using industries, but as an addition it was of interest to compare WFP methods. A life cycle assessment (LCA) was made on the case study's baseline technology scenario, and the WFP methods were used to assess water use based on inventory data.

The methods to compare were selected based on the criteria that they should include both water use and emissions to water. They were also selected to reflect a general expression of water footprint in terms of volume, instead of focusing on a certain area of protection. The results differ by an order of magnitude of 10 between the methods. Since the input of water was the same in both calculations, the results clearly show a difference between the methods.

The amount of considered emissions is one of various reasons to the difference, where the H2O-method includes a number of emissions while the WFN-method only considers one. Other differences are that the first method counts for the water scarcity situation, based on a water scarcity index (WSI), and relate local water use to global water use, which is not accounted for in the second method. Also, the characterization factors for the first method are based on country level while the characterization factors for the second method, are based on watershed level.

The result indicates that it is not possible to compare WFP calculated with different methods, even if the calculations are based on same data. This may be a problem as the producer can select a method favouring their WFP. For this reason, there is a need for a WFP reference method, which also expresses how to handle geographical and temporal aspects, as well as how to assess degradative water use. Knowledge dispersion would probably improve wider requests and therefore promote actors to work against this reference method.

This study shows that most of the water use in this case study takes place in the background processes of the life cycle. The result illustrates the importance of having a life cycle approach when discussing WFP for a product or production process.

WFP has potential to assess environmental impact from water use. The development of WFP methods indicates an increased interest for sustainable water use and as a possible continuation, the applicability of WFP can be further investigated.

Keywords
Water footprint, Water footprint method, Water use

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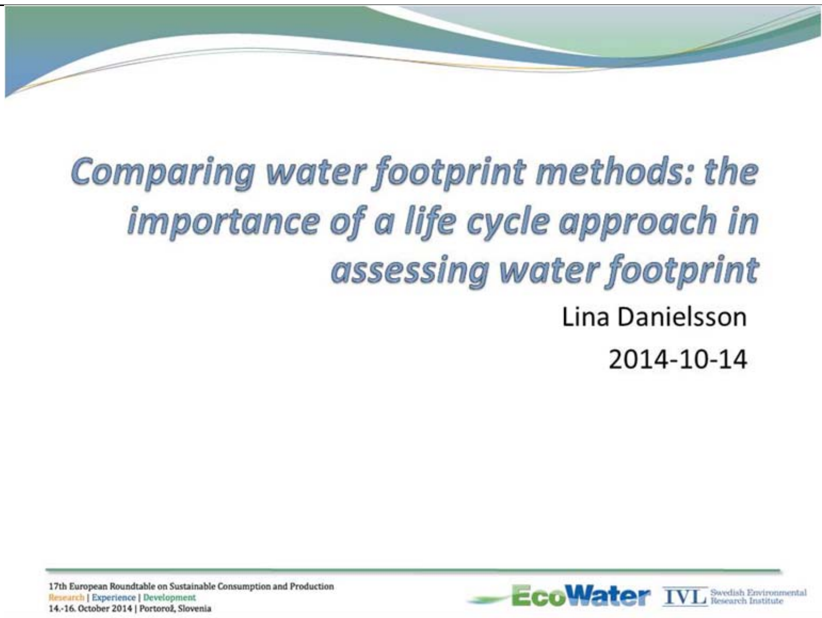
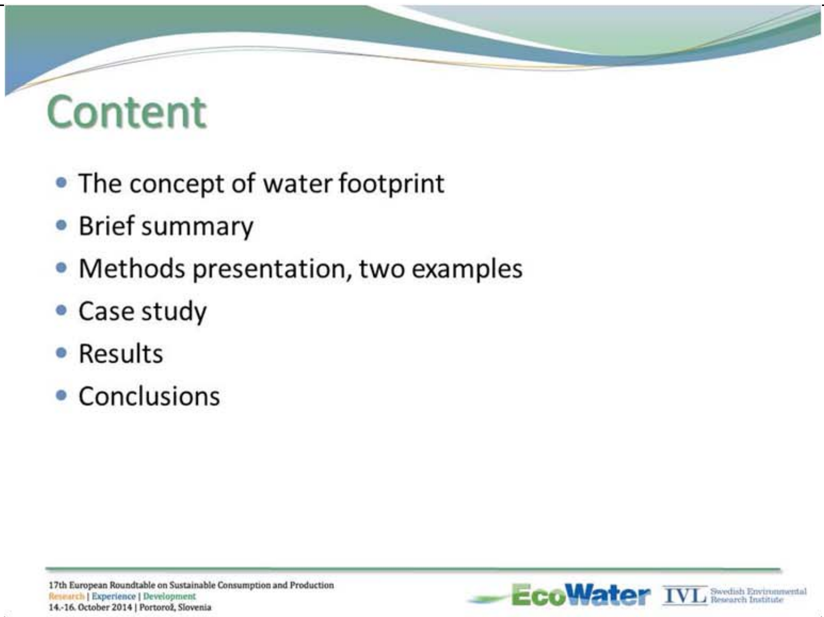
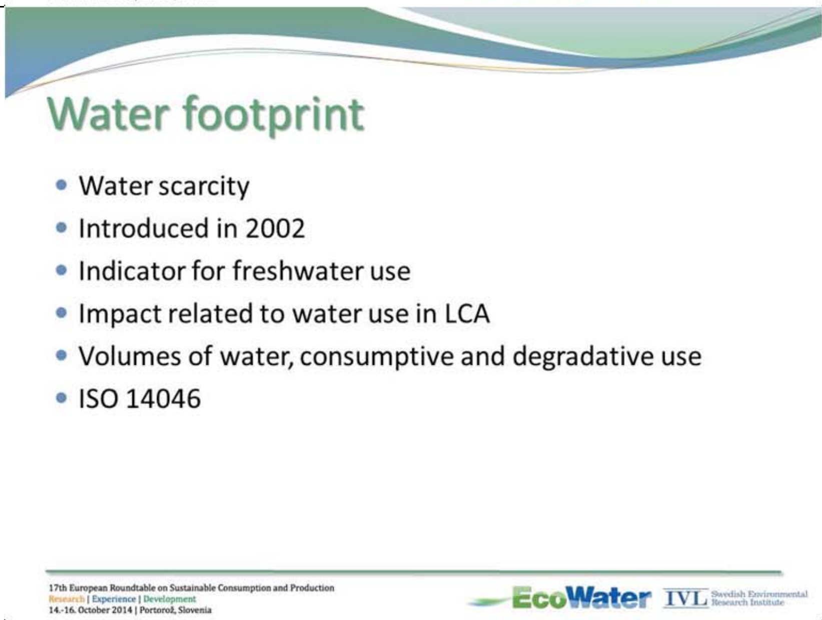
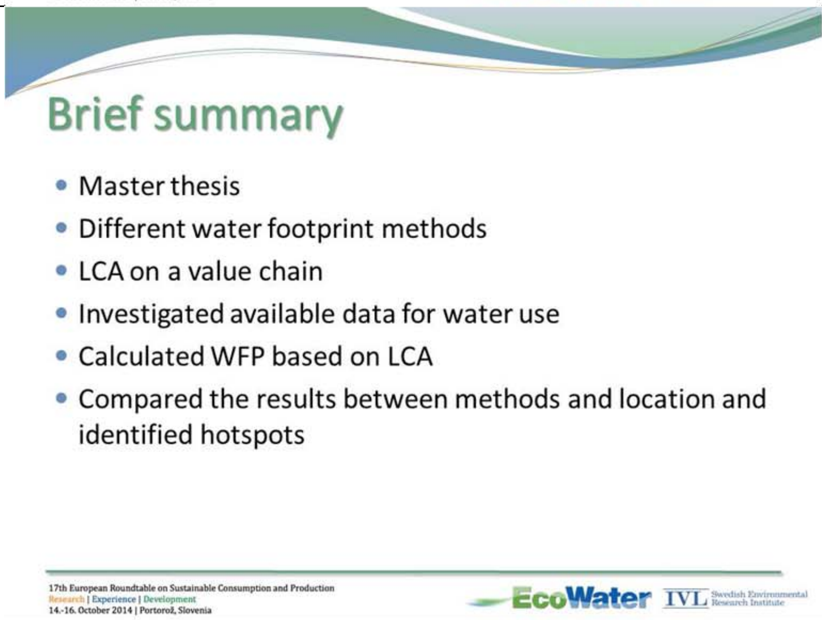
2.12.2 Presentation

(1)



(2)	
(3)	
(4)	

Content
The concept of water footprint
Brief summary
Methods presentation, two examples
Case study
Results
Conclusions
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Water footprint
Water scarcity
Introduced in 2002
Indicator for freshwater use
Impact related to water use in LCA
Volumes of water, consumptive and degradative use
ISO 14046
17th European Roundtable on Sustainable Consumption and Production
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Brief summary
Master thesis
Different water footprint methods
LCA on a value chain
Investigated available data for water use
Calculated WFP based on LCA
Compared the results between methods and location and identified hotspots
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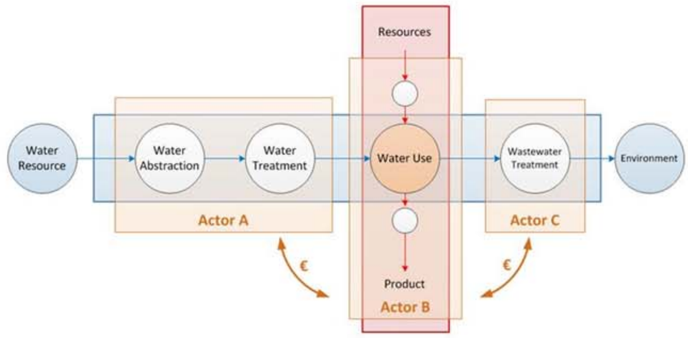
(5)	**The H_2Oe-method** • Sum of consumptive (CWU) and degradative (DWU) use • Global perspective • Local water use • WSI – Water stress Index • Recipe points – eutrophication and ecotoxicity $Water\ footprint\ (H_2Oe) = CWU(H_2Oe) + DWU(H_2Oe)$ $CWU(H_2O) = \sum_i \frac{CWU_i \times WSI_i}{WSI_{global}}$ $DWU(H_2Oe) = \frac{RECIPE\ points\ (emission\ to\ water\ for\ product\ system)}{RECIPE\ points\ global\ (average\ for\ 1l\ consumptive\ water\ use)}$ 17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater IVL Swedish Environmental Research Institute
(6)	**The Water Footprint Network (WFN) method** • Blue, green and grey water • Degradative water use – grey water – for one emission • A critical dilution volume based on reference values $WF = WF_{blue} + WF_{green} + WF_{grey}$ $WF_{proc,grey} = \frac{L}{c_{max} - c_{nat}}$ 17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater IVL Swedish Environmental Research Institute
(7)	**The EcoWater Water Use System**  17th European Roundtable on Sustainable Consumption and Production Research | Experience | Development 14.-16. October 2014 | Portorož, Slovenia EcoWater IVL Swedish Environmental Research Institute

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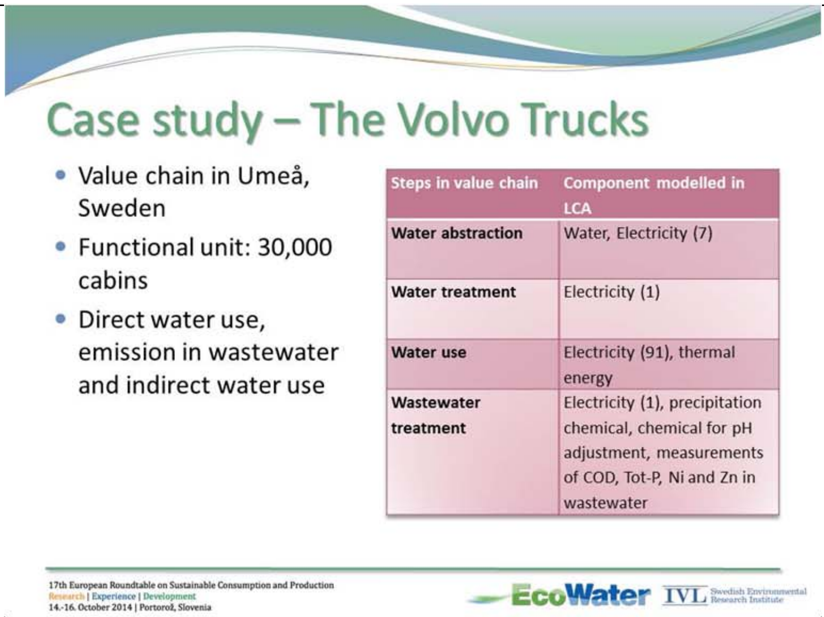
Case study – The Volvo Trucks
Value chain in Umeå, Sweden
Functional unit: 30,000 cabins
Direct water use, emission in wastewater and indirect water use
Steps in value chain
Component modelled in LCA
Water abstraction
Water, Electricity (7)
Water treatment
Electricity (1)
Water use
Electricity (91), thermal energy
Wastewater treatment
Electricity (1), precipitation chemical, chemical for pH adjustment, measurements of COD, Tot-P, Ni and Zn in wastewater
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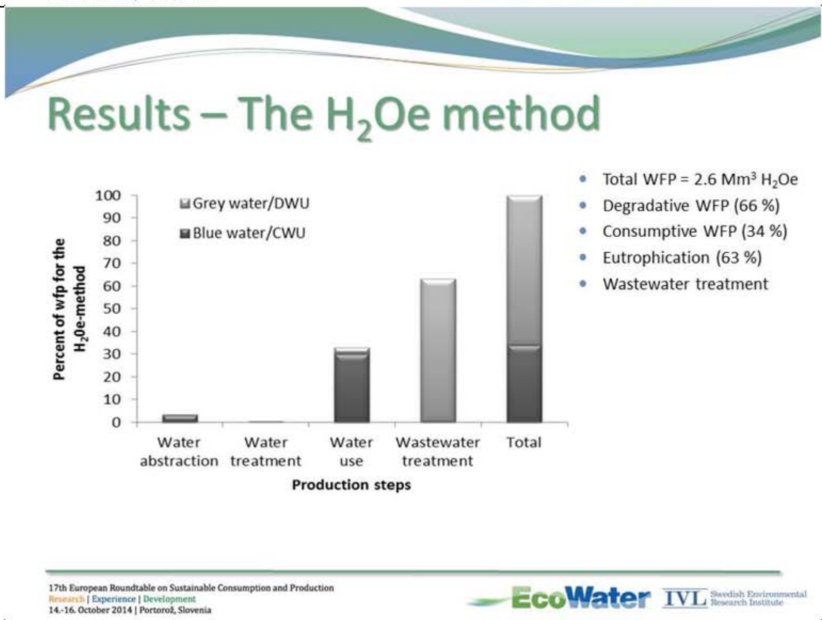
Results – The H2Oe method
Grey water/DWU
Blue water/CWU
Percent of wfp for the H2Oe-method
100
90
80
70
60
50
40
30
20
10
0
Water abstraction
Water treatment
Water use
Wastewater treatment
Total
Production steps
Total WFP = 2.6 Mm3 H2Oe
Degradative WFP (66 %)
Consumptive WFP (34 %)
Eutrophication (63 %)
Wastewater treatment
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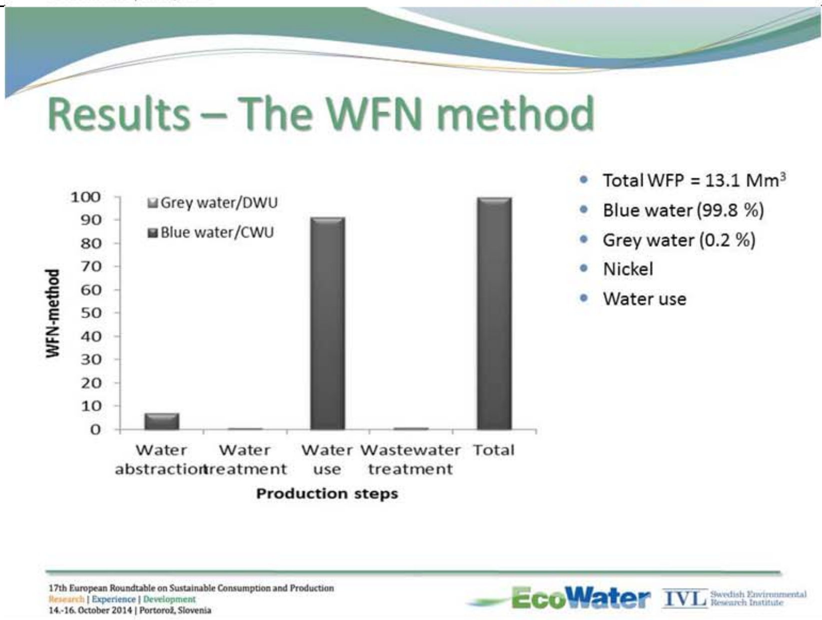
Results – The WFN method
Grey water/DWU
Blue water/CWU
WFN-method
100
90
80
70
60
50
40
30
20
10
0
Water abstraction
Water treatment
Water use
Wastewater treatment
Total
Production steps
Total WFP = 13.1 Mm3
Blue water (99.8 %)
Grey water (0.2 %)
Nickel
Water use
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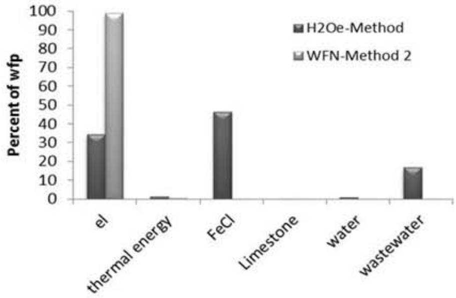
(11)

Results - Hotspots



- H2Oe-method
  - the precipitation chemical (46 %)
  - electricity (43 %)
- The WFN-method
  - electricity (99 %)

(12)

Conclusions

- Most of the water footprint occurs in background processes, therefore a life cycle approach is important when assessing water footprint
- Water footprint calculated with different methods are not comparable, because water footprint vary, even if the calculations are based on the same data
- (It is important that water use are considered separate from other environmental impacts in LCA)
- There is a need to unify water footprint methodologies – ISO 14046 is an attempt to that

(13)

Thank you for your attention

For more information, see http://environ.chemeng.ntua.gr/ecowater