DESSIN

DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

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MS34b Final report

Executive summary
Project context and main objectives
Main S&T results
Potential impact, dissemination and exploitation

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 619039

TITLE OF THE REPORT

MS34b Final report

SUMMARY

DESSIN demonstrated and promoted innovative solutions for water scarcity and water quality, and thus the implementation of the Water Framework directive (WFD). The project showed the value of those solutions for the water sector and society by demonstrating a methodology for the valuation of ecosystem services (ESS) as catalyser for innovation. By this twofold approach, DESSIN was able to show how innovative solutions in the water cycle can increase the value of the services provided by freshwater ecosystems, enabling a more informed selection of the most promising solutions in regards to their impact on the water body and their economic implications. Scientists, public and private water management organisations and end-users, technology providers (SMEs), supporting RTD experts and relevant public authorities were collaborating within DESSIN to test, validate and demonstrate innovative solutions at five demo sites across Europe with special focus on urban areas. The solutions included technological, monitoring, modeling and management approaches for a more resource-efficient and competitive water sector in Europe, such as decentralized water treatment units, real time control of large scale systems, sewer mining and storage of freshwater in aquifers, among others. The demo sites Emscher (Germany) and Hoffselva (Norway) focussed on ecosystem services related to water quality/Water Framework Directive and the demo sites Westland (Netherlands), Athens (Greece) and Llobregat (Spain) to water scarcity.

MILESTONE NUMBER	WORK PACKAGE
MS34	WP51, WP52
LEAD BENEFICIARY	**DELIVERABLE AUTHOR(S)**
IWW	David Schwesig, with comprehensive contributions by all WA and WP leaders

QUALITY ASSURANCE

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List of Acronyms and Abbreviations

AMI	Advanced Monitoring Infrastructure
ASR	Aquifer Storage and Recovery
ASRRO	Aquifer Storage and Recovery – Reverse Osmosis
BOD	Biological Oxygen Demand
CICES	Common International Classification of Ecosystem Services
COD	Chemica oxygen demand
CSO	Combined Sewer Overflow
DoW	Description of Work, i.e. Annex I to the Grant Agreement (GA)
DPSIR	Drivers, Pressures, State, Impact, Response
Dx.y	Deliverable number y of work package number x (x,y: variables)
EC	European Commission
EEA	European Environment Agency
ESS	Ecosystem Services
GA	Grant Agreement (No 619039 for DESSIN)
HGGI	Hybrid Grey-Green Infrastructure
HRF	High Rate Filtration
ICT	Information and Communication Technology
MAR	Managed Aquifer Recharge
MBR	Membrane Bioreactor
MSx	Milestone X (X: variable)
Mx	Project Month X (X: variable)
NBS	Nature-Based Solutions
PAC	Project Advisory Committee
PSB	Project Steering Board
RO	Reverse Osmosis
RTC	Real Time Control
RTD	Research and Technical Development
SME	Small and Medium-sized Enterprises
SS	Suspended Solids
TOC	Total organic carbon
TSS	Total suspended solids
TSS finde	Fraction of TSS y 63µm
Tx.y	Task number y of work package number x (x,y: variables)

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US-EPA	United States Environmental Protection Agency
WA	Work Area
WAMT	Work Area Management Team
WFD	Water Framework Directive
WP	Work Package
WssTP	Water Supply and Sanitation Technology Platform
WWTP	Waste Water Treatment Plant

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Executive summary

DESSIN demonstrated and promoted innovative solutions for water scarcity and water quality / the implementation of the Water Framework directive (WFD) and showed the value of those solutions for the water sector and society by also demonstrating a methodology for the valuation of ecosystem services (ESS) as catalyser for innovation. By this twofold approach, DESSIN was able to demonstrate how innovative solutions in the water cycle can increase the value of the services provided by freshwater ecosystems, enabling a more informed selection of the most promising solutions in regards to their impact on the water body and their economic implications. Scientists, public and private water management organisations and end-users, technology providers (SMEs), supporting RTD experts and relevant public authorities within DESSIN were collaborating to test, validate and demonstrate innovative solutions at five demo sites across Europe with special focus on urban areas. The solutions included technological, monitoring, modeling and management approaches for a more resource-efficient and competitive water sector in Europe, such as decentralized water treatment units, real time control of large scale systems, sewer mining for urban irrigation, and storage of freshwater or pre-potable water in aquifers.

The demo sites Emscher (Germany) and Hoffselva (Norway) contributed to ecosystem services related to water quality/Water Framework Directive and the demo sites Westland (Netherlands), Athens (Greece) and Llobregat (Spain) to water scarcity.

The final results of DESSIN are:

1. An analytical framework to evaluate and account impacts from changes in ESS suitable to the water sector, finally resulting in a ready-to-use ESS evaluation module for practitioners; - validated, demonstrated and transformed into a software module.

2. Guidance for practitioners and policy makers linking good practice and lessons-learned for innovation-friendly governance regimes and financing options, within an ESS framework.

3. Solutions for Water Quality / WFD implementation, implemented and evaluated by use of the ESS approach: (i) enhanced efficiency of decentralised treatment of combined sewer overflow by a new cross-flow lamella settlers and innovative high-rate filters, (ii) a fully automated real-time control system to minimize combined sewer overflow.

4. Solutions for Water Scarcity, implemented and evaluated by use of the ESS approach: (i) new combination of sewer mining technology with distributed ICT to enable decentralised sewer treatment for irrigation e.g. of urban green; (ii) a solution for sustainable freshwater supply from brackish/saline aquifers by combining Aquifer Storage and Recovery (ASR), desalination and innovative well design; (iii) a flexible ASR system to increase freshwater availability in Mediterranean coastal regions by deep injection systems able to deal with variable water qualities.

5. Maximised market reach of DESSIN solutions by (i) Market analyses for DESSIN technologies; (ii) a sample commercialisation process for DESSIN SMEs; (iii) business environment reports water quality and scarcity solutions; (iv) a monitoring & evaluation system for innovations; (v) showcases at five sites in Europe; (vi) promotional and educational material such as videos and leaflets on key results.

We actually demonstrated the complete set of DESSIN solutions in real environment near full-scale case studies, and at all five demonstration sites follow-up activities are now in place, ranging from additional testing to setting up full-scale applications, local replication and regional roll out.

1 Project context and main objectives

The main objectives of DESSIN were

- to demonstrate and promote innovative solutions to water-related challenges with a focus on: (i) water quality issues related to the implementation of the Water Framework Directive (WFD) and (ii) water scarcity;
- to develop and demonstrate a methodology for the valuation of ecosystem services (ESS) as catalyser for innovation in water management;

To this purpose, DESSIN has launched demonstration projects of innovative solutions to challenges related to (i) the effective implementation of the Water Framework Directive (WFD) and (ii) water scarcity with a special focus on urban areas. The solutions were integrating technological, monitoring, modeling and management approaches for a more resource-efficient and competitive water sector in Europe.

As a second key feature, an Evaluation Framework to assess the sustainability aspects of the mentioned solutions and to valuate changes in ecosystem services (ESS) of water bodies that result from the implementation of these solutions has been developed and applied.

By adopting this twofold approach, we have demonstrated how innovative solutions integrated in the water cycle can increase the value of the services provided by freshwater ecosystems while assuring sustainability, thus generating additional incentives and arguments for their market uptake and practical implementation. This will support innovation and competitiveness in water management by enabling a more informed selection of the most promising solutions, as regards their impact on the water body and their economic implications.

The whole project was centered around a suite of carefully selected sites across Europe, (Emscher - Germany, Hoffselva – Norway, Westland – Netherlands, Athens – Greece, Llobratag – Spain), representative of global major water challenges, where we brought together public and private water management organisations and end-users, technology providers (SMEs), supporting RTD experts and relevant public authorities to demonstrate this approach.

The detailed objectives of DESSIN were as follows:

1.1 Objectives of Work Area 1 (WP 11-13)

The overarching objective of Work Area 1 was to develop the new tools, accompanying knowledge and practical examples necessary to help bring the Ecosystem Services Approach (ESA) out of the books and into practice and to expand the knowledge base on innovation-friendly governance regimes and financing options. This was key for DESSIN to shed light on how, to what extent, and under which circumstances the ESS concept can be used as a catalyser for innovation.

The specific goals of Work Area 1 included:

- Reviewing and outlining the state-of-the-art in ESS evaluation techniques and methodologies
- Developing a framework to evaluate the changes in ESS associated with technical or management solutions implemented at the water body, sub-catchment or catchment level
- Developing a framework to assess governance regimes, with particular focus on conduciveness to innovation
- Testing and validating the new frameworks through their practical application in the DESSIN mature sites (Aarhus, DK; Emscher, DE; and Llobregat, ES / Ebro, ES)
- Analysing financing mechanisms and economic policy instruments conducive to water sector innovations
- Collaborating with Work Area 2 to migrate the ESS Evaluation Framework into a software module
- Collaborating with Work Area 3 to ensure a smooth application of the ESS Evaluation Framework in the demo sites

1.2 Objectives of Work Area 2 (WP 21-23)

Work Area 2 aimed at developing and enabling innovative solutions to improve water quality in receiving waters and to handle water scarcity across the demonstration sites in DESSIN.

The effect of these solutions on the ESS at the different demonstration sites was evaluated in WA3 with the standard methodology developed in WA1. The development of the software to work with the ESS evaluation methodology of WA1 in WA3 was developed in WA2.

The innovative solutions developed in WA 2 were:

- Two solutions for local treatment of CSO overflows (WP21): a new system with modular cross-flow lamella settling units for application in CSO holding tanks (T21.2), a high rate filtration system for implementation on the overflow pipe from a CSO (T21.2). Additional two tasks focus on ICT technologies for integration of local CSO treatment units (T21.3) and for reducing CSO overflow volumes by Real Time Control (RTC) (T21.4).
- Distributed reuse technologies (both modular and mobile) (WP22): sewer mining technologies (T22.1) and Aquifer Storage and Recovery (ASR) systems as potential sources for drinking water (T22.3), and agricultural or industrial water (T22.2).
- Software framework for ESS valuation (WP23).

1.3 Objectives of Work Area 3 (WP 31-35)

The objective of Work Area 3 was to demonstrate at five representative sites across Europe the potential of a range of innovative solutions

- to tackle two major water challenges (water quality and water scarcity)
- to increase the value of ecosystem services of the water bodies

Work Area 3 integrates the technology solutions developed in Work Area 2 as well as the Ecosystem valuation approach from Work Area 1. The five full scale demonstrations including their main objectives are listed in the table below.

Table 1: DESSIN demonstration sites and work packages and their specific objectives

Demonstration	Objective
WP31 Emscher (DE)	Improved water quality in strongly urbanised areas by implementing novel and cost efficient treatment and regulation solutions for existing CSO facilities that increase value of the ESS and serve as a pilot for a possible implementation following the reconversion process of the whole Emscher system.
WP32 Hoffselva (NO)	Improved water quality in peri-urban areas using innovative decentralised CSO treatment solutions that enable cost efficient, sustainable mitigation of an overloaded sewer system and increased value of the ESS.
WP33 Westland (NL)	Enhanced fresh water availability in brackish coastal zone through novel ASR systems.
WP34 Athens (GR)	Enhanced urban water availability through decentralised sewer mining solutions
WP35 Llobregat (ES)	Increased fresh water availability in Mediterranean coastal region using flexible ASR systems.

1.4 Objectives of Work Area 4 (WP 41-42)

The objectives of Work Area 4 were divided in:

Objectives of the dissemination and exploitation of the project results towards the scientific and commercial sector (Work Package 41):

- To ensure a successful run-time and final dissemination of the project results to all relevant stakeholders and target audiences by developing a project branding, setting up a website, producing and distributing different dissemination and communication materials and establishing demo-sites as showcases.
- To facilitate the market deployment and exploitation of the technologies through the organization of different events at the participating utilities and tailored workshops.

Objective of the Route to Market (Work Package 42):

- To maximize the market reach and impact of the water technologies, methodologies and innovative solutions developed in WA1 and WA2 and demonstrated in WA3.

In detail, the objectives of Work Package 42 were:

- To support supply side push for water technologies by developing sample development approaches.
- To assure international (European and beyond Europe) market uptake of water technologies, by addressing and overcoming market barriers and promoting solutions.
- To create demand side dynamics to further stimulate water technology innovation.

1.5 Objectives of Work Area 5 (WP 51-52)

The objective of this Work Area was to co-ordinate and to manage the progress of the project, in order to ensure that the objectives will be met. This included the coordination of activities among the Work Areas and Work Packages, facilitation of the internal communication, organization of meetings, guidance of the decision-making processes, reporting to the European Commission, monitoring of progress, quality control of the project deliverables, re-adjustment of the work if necessary and taking care of contractual matters.

2 Main S&T results/foregrounds of the project

2.1 Work Area 1 – Evaluation Framework

While the main exploitable foreground to come out of Work Area 1 was the DESSIN ESS Evaluation Framework, other methodologies, guidance documents and research results were generated which contribute to furthering the knowledge on ESS valuation and innovation policy.

2.1.1 State of the art report on ESS evaluation

This report (D11.1) set the groundwork to support the conceptual and practical development of the DESSIN ESS Evaluation Framework. It briefly presents the state of affairs in late 2014 regarding the measurement of changes in ESS, including description of existing classification systems, analytical frameworks and economic valuation methodologies.

The report lays out the state of affairs regarding the tools and techniques that could be used for evaluating changes in ESS. Frameworks to illustrate the interactions between society and the environment are described and the most accepted ecosystem typologies and ecosystem service categories are identified. Furthermore, an overview of the current discussions regarding the links between ecosystem biophysical functions and processes and the provision of ESS is given. Criteria to identify and select indicators/proxies to investigate the links between changes in water status and changes in ESS are suggested. The challenges associated with spatial and temporal variations of ESS are also explored. The document includes a review of existing economic valuation methods, their strengths and weaknesses, as well as their practical application within the water sector. Finally, the root elements of the sustainability assessment tool that would later be integrated into the DESSIN ESS Evaluation Framework are described and an approach to define and measure sustainability is presented.

This document can prove a useful resource for anyone conducting an updated review of the literature on ESS assessment methodologies.

2.1.2 The DESSIN ESS Evaluation Framework

The DESSIN ESS Evaluation Framework (D11.2) is a practice-oriented, tested and validated framework to evaluate changes in ESS that are associated with technical or management solutions implemented at the water body, sub-catchment or catchment level. The main purpose of running an evaluation using this framework is to facilitate the application of the ESA in the appraisal of the effects of innovative solutions on freshwater ecosystems and their services. The development process of the framework included a testing of its practical application on the DESSIN mature sites Aarhus, Emscher and Llobregat. This allowed a timely feedback loop to improve and fine-tune the framework on the basis of direct user recommendations. The improved final version of the framework was then applied on the DESSIN demonstration sites, which served to reaffirm its validity before the end of the project.

The dual need of having a scientifically-sound, yet practitioner-friendly framework for the evaluation of changes in ESS led to structuring it as a multi-document package. The DESSIN framework thus consists of a suite of structured reference materials that provides the instructions necessary to run an evaluation: the DESSIN Cookbook, a Companion Document, a supplementary material catalogue, a case study reporting template and a webinar. All these materials fed into the software module developed in WP23 and integrated into the existing MIKE Workbench Decision Support System to ease usability, promote the uptake of the framework and to enable the use of computational models in evaluations.

The DESSIN cookbook is the main interface of the DESSIN framework. It guides the user through the different parts of the evaluation, detailing the procedural steps to follow. Examples from DESSIN's mature case studies are used throughout the cookbook to illustrate this procedure. The cookbook is written as a practical guidance document and is meant to be read as a step-by-step instruction manual to fill in the evaluation template. The latter gives the user a structured outline to present evaluation outcomes.

The Companion Document presents the theoretical background considered in the development of the DESSIN framework and explains its conceptual basis. It contains a glossary of terminology which was discussed and agreed by the interdisciplinary team in charge of developing and applying the framework in the mature case studies. The document includes extensive treatment of the concepts underpinning the different parts of an evaluation.

The supplementary material catalogue provides lists of drivers, pressures, state parameters, beneficiary types, impact indicators and economic valuation studies that the user can refer to when conducting an evaluation. The catalogue functions as a quick reference directory that illustrates possible associations between ESS classes, beneficiary types and the different elements of the DPSIR scheme. The catalogue was created based on a review of the relevant literature and the results of the DESSIN mature case studies, which comprised expert knowledge from the direct users of the framework supplemented by stakeholder feedback gathered in workshops. A database of economic valuation studies was compiled and included as a way of showing the user how different valuation methodologies are applied in practice.

By focusing on local-scale evaluations of ESS, the DESSIN framework has attempted to make ESS assessments more accessible, leaner, and yielding results that are more directly relatable and actionable for stakeholders and decision-makers. The framework could be exploited in the immediate future to complement the large ESS assessments being undertaken at the EU and national levels.

2.1.3 Quantified ESS for 3 mature sites including recommendations for application

This integrated report (D13.1) illustrates the results of the application of the DESSIN ESS Evaluation Framework on three mature sites: Aarhus, DK; Emscher, DE; and Llobregat, ES. The individual cases provide extensive and detailed insight into the practical application of the framework and give the reader a clear idea of the type of results that an evaluation yields (quantified ESS, measurements of change in ESS provision associated to specific measures implemented, measurements of sustainability on five different dimensions). At the same time it exemplifies how such evaluation results can be used for providing arguments on the values generated by the implementation of the respective solutions.

The application of the DESSIN ESS Evaluation Framework on each of the case studies consisted of the following steps:

- Description of study area and relevant drivers and pressures
- Selection of key ESS affected by the innovative solutions
- Identification of relevant indicators to measure changes in ecosystem status and service provision and use
- Quantification of the case relevant ESS
- Valuation of the final ESS
- Assessment of the innovative solution with regard to sustainability aspects

The mature sites represent case studies where innovative solutions had already been implemented in the past. Therefore, it was possible to compare the status before and after the solution was implemented. The case studies are distributed throughout Europe in order to cover a broad geographical range with diverse environmental conditions and social dimensions. Furthermore, the case studies offer an illustration of a wide variety of ecosystem service types targeted with restoration projects. Each case was included for specific reasons and has a specific focus.

The innovative solution in the Aarhus mature case study is the real-time control of a full urban water cycle with sewers and wastewater treatment plants as well as recipient waters such as lakes, river, and a harbor. All these elements are combined into one model-based real-time decision support system (DSS). The aim of this real-time DSS system was to adapt Aarhus' water system to climate change related challenges and to raise the recreational potential in the city of Aarhus via an improvement of the water quality. Thus, this case has a special emphasis on water quality issues and recreational values.

The Emscher site applies the ESS Evaluation Framework to individual sections of the Emscher river network for the status before and after the large-scale Emscher restoration was realized. Subsequently, the results are transferred across the multi-site case study allowing a prognosis for the whole catchment. Service provision is, in the end, related to the costs of the restoration project for the river network as a whole.

The Llobregat study has a focus on the economic valuation of changes in ESS provision resulting from the implementation of infiltration ponds. These ponds were created in order to replenish the groundwater reserves and provide drinking and non-drinking water to the Barcelona area. The current and past status and the resulting benefits are assessed for individual beneficiaries.

2.1.4 Analytical framework for governance regime assessments

The analytical framework for governance regime assessments (D12.1) is a tool for analyzing the performance of urban water governance and its capacity to promote innovation uptake. This is in contrast with previous theoretical frameworks which either did not focus on urban water governance or, when they do, aim to contribute to governance theory rather than supporting policy and decision-making.

The framework follows a step-wise approach which entails 1) using personal knowledge, documentary evidence and close contacts for data collection and analysis; 2) identifying key knowledge gaps and carrying out a small number of interviews with relevant knowledge holders; and 3) expanding as necessary.

Rather than developing a new theoretical approach, the governance assessment framework in DESSIN primarily builds on the framework developed during the INTERREG DROP project (and previously the EU FP EUWARENESS project) and consists of three steps. The first step of the DESSIN governance assessment framework involves introducing the case-study, its broad characteristics, and the innovation(s) of interest. The second step involves answering the series of open questions regarding governance factors on innovation uptake. The third step consists in moving from the question-answer format into a coherent storyline of innovation uptake and governance regime influence.

The heart of the governance assessment tool is the series of open questions that guide the exploration of (contextual) factors influencing the uptake of technologies in the water sector, focusing on particular sub-national and national circumstances, as well as considering the role of European and international factors. The questions are not designed to be interview questions, although this does not prevent their use in interviews. They mainly serve to diagnose the innovation uptake, guide the analysis in a comprehensive manner, ensure consistency and comparable results, and support the development of storylines. The questions suggested in the framework are model questions that can be used as drafted, or adapted to the particular context/information gaps.

The series of questions is accompanied by a guide presenting a structured approach to developing storylines of innovation uptake. It provides guidance on how to select the cases of innovation uptake, how to answer the questions of the governance assessment tool, and how to develop the historical storylines.

The governance assessment tool is fit for purpose and can continue to be exploited to evaluate the favorableness to innovation of new governance implementations at different administration levels.

2.1.5 Best practice and constraints to innovation uptake. A guide for policy-makers and practitioners

Two brief guides targeted to i) policy-makers and practitioners and ii) innovators (water technologies developers and water utilities) synthesise the results of applying the DESSIN governance assessment tool in the mature case study sites and showcase examples of how to use or promote governance for pushing the uptake of technological innovations in urban water management (D12.3).

Lessons learned, enabling factors, best practices and constraints to the uptake of innovations are outlined into key recommendations targeted to the two audiences. These recommendations highlight critical governance factors supporting innovation uptake such as commitment to compromise, the necessity to build political support and the role of coalitions. Recommendations also present the role of discursive strategies and partnership design, as well as that of regulative, economic and communicative instruments, in creating barriers and opportunities to initiate and secure change. The guides also highlight the importance of finding multiple benefits and enhancing the delivery of several ecosystem services.

2.1.6 Report on financing approaches conducive to water sector innovation

DESSIN's report on innovative and innovation-friendly modes of governance, financing and payment (D12.2) presents the results of an assessment of the role of economic instruments in promoting innovation uptake in the water sector. The assessment considers the role of specific policy instruments such as public procurements, pricing policies and financing frameworks. The potential role of Payments for Ecosystem Services for innovation uptake in urban water management is explored. A list of financing and payment mechanisms is provided as well as templates for different policy instruments, presenting their objectives, structure, and existing examples of their application worldwide.

2.2 Work Area 2 – Development and Enabling of Innovative Solutions

The WA2 was structured based on the challenges addressed (Figure 1): water quality, covered by work package (WP) 21 and water scarcity, under WP22; the work area included an additional WP, WP23, devoted to the development of the ESS module for decision support systems.

The main purpose of Work Area 2 was to prepare and support the actual demonstration of the solutions in a real environment, which was carried out in WA3. Hence, key results of WA2 were directly utilized for real application by WA3, and the result of this final evaluation of the solutions done in WA3 will be key to the further impact, exploitation and market uptake of the solutions.

Figure 1 DESSIN WA2 structure

2.2.1 Water Quality technological solutions and results

The measures to reduce the overflow volumes or to improve the water quality in discharges from Comined Sewer Overflows (CSOs) are two complementary approaches the utilities can implement to solve the water quality challenges in receiving waters and increasing the value of the ecosystem services. The innovative solutions developed by WP21 in DESSIN combine technologies acting at local and system level.

The solutions for local treatment of CSO overflows are two: a new system with modular cross-flow lamella settling units for application in CSO holding tanks and a high rate filtration (HRF) system, which does not require a holding tank, for implementation on the overflow pipe from a CSO. Cross-flow lamella settlers allow the flow to pass an inclined lamella plate horizontally while the sludge may slide down in a perpendicular direction, to avoid any re-mixing of sludge into the inflow. The HRF system has a specially designed filter media that has an optimal shape to capture debris, organic material and particles. The cross flow lamella settler was developed by the German company Umwelt- und Fluid-Technik Dr. H. Brombach GmbH (UFT), combined with on-line monitoring and wireless data communication supplied by the Norwegian company LKI. The HRF has been developed by the Norwegian company Inrigo AS (Inrigo) also in combination with on-line monitoring and data communication from LKI (both described in D21.1).

At system level, real time control of large-scale systems can be used to reduce overflowing of CSO by controlling the hydraulic load in different parts of a wastewater network. This requires a hydraulic model of the network system and optimised performance of the available control hardware in the system, *e.g.* actuator as valves, gates and volumes. The solution developed in DESSIN is the ADESBA-control box, which is an innovative fully automated real time control system to minimize combined sewer overflow. The ADESBA-RTC system was developed by the German company SEGNO Industrie Automation GmbH (D21.2).

The focus of WP21, coordinated by SINTEF, has been i) on site-specific testing of the HRF solution in the Hoffselva site, ii) development and testing of monitoring and control solution of the cross-flow lamella settler plant in the laboratory first and in Hoffselva site afterwards and iii) on the development and testing of the software for the ADESBA system for RTC to reduce CSO volume.

2.2.1.1 Cross-flow lamella settler

The cross-flow lamella settler was developed in WP2.1 as a prototype by UFT. The modular cross-flow lamella settler unit allows the local treatment of combined sewer overflows from tanks.

In WA2, model tests were conducted in a reduced-scale model. The model tests and interpretation of results have been conducted by UFT and UDE.

The objective of the model tests, using spherical plastics beads as model sediment, was to investigate the behaviour of sediments and to establish efficiency curves for given flow and sediment characteristics.

The experiments were conducted using tap water as well as salt water of different density in order to vary the settling velocity as the most essential parameter. Steady-flow efficiency curves were gained which showed that the efficiency decreases with increasing surface load as well as with decreasing settling velocity. The evaluation was made in dimensionless form to allow scaling and possibly transfer to prototype size.

Comparison with similar curves from upflow lamella model experiments was possible under some assumptions, but only slightly better efficiency could be obtained. One essential fact is the coaction of the settler modules and the vessel in which they are placed. Moreover, the results indicated that there is re-mixing of already settled sediments into the flow. Generally, it was found that the overall sediment removal efficiency of a lamella settler is not governed by the sedimentation process only, but also to a large part by secondary effects such as the flow-induced sediment transport on the settler surface and, particularly for real sewage sediments, by sticking to the lamella surfaces and by formation of sediment flakes affecting sliding-down. This made it difficult to reliably predict the performance of real lamella settlers from model test data. However, some findings indicate that the prototype efficiency should be considerably better than derived from model data. It was thus essential to test the settling efficiency of the prototype lamella settler by container tests at Emscher and Hoffselva (WA3).

2.2.1.2 High rate filtration system

An innovative high rate filtration (HRF) system has been developed and applied for treatment of a combined sewer overflow (CSO) by Inrigo AS from Norway. In WA2, a container type HRF plant was built to investigate and later demonstrate the treatment efficiency for treatment of CSO. The HRF can be installed on the CSO outlet of a wastewater pipe for smaller structures without a holding tank.

The HRF plant was placed at Hoffselva, Norway, where site specific testing has been performed to give basis for final design. The new HRF system for CSO has special filter media which are floating in the filter bed. The filter media is designed to have optimal shape to capture debris, chemical oxygen demand (COD) and suspended solids (SS) with high void ratio. There is no chemical addition and pre-treatment required for this new HRF system. During the operation, filtration and backwash are switched by a backwash valve that is closed and opened, controlled by inlet water level. Filtration water flow is not stopped during backwashing. The motorized equipment consists only of inlet pumps (no pumps needed if gravity flow is available) and a compressor for pneumatic valves. During rainfall, CSO raw water comes in from the distribution channel flowing upwards through the filtration layer. Sewage garbage is deposited on the surface of the filter bed, while SS and COD removal will take place also in the internal parts of the filter bed. As filtration continues, and filter media becomes clogged, the water level on the inlet side will rise. When a predetermined maximum water level is reached, the high-speed drain valve opens automatically and starts backwash. Filtrated water flows downward by gravity and sewage garbage, SS and COD accumulated in the filter media is discharged. The backwash cycle requires only a minute, and no filter media flows out during backwash.

Eleven (11) CSO events were recorded during the first testing and demonstration period, from September 2015 until May 2016. Test results indicated that the HRF solution was a promising technology to reduce emissions of particulate pollutants from CSO. Up to 80% of SS removal and 75% of COD removal were documented during the first flush. The overall removal of SS and COD were about 47% and 56%. Nutrient removal was relatively low because of the high fraction of soluble nitrogen and phosphorus in CSO. However, 6.3% TN and 15% TP were retained together with particles. The HRF system also showed promising treatment efficiency for heavy metals with 48% Al, 48% Zn, 57% Cu, and 31% Cr removed, respectively.

2.2.1.2.1 Integration of local CSO treatment units by monitoring and data communication

An on-line monitoring system has also been designed and implemented by LKI with on-line sensors, a data acquisition manager with wireless connection enabling data transfer and remote control of the plant.

The on-line monitoring system allowed to monitor the state of the HRF and performance during CSO events. This was possible by logging of plant sensors and installed turbidity sensors on the inlet and outlet to a local data logger. This data logger was set to log data every 10 seconds, but had the possibility to start logging upon triggering of an alarm or set-point, and the frequency of data collection could be adjusted. The locally stored data were transferred to SINTEF using wireless transfer and an internet based access to the local computer with the logged data.

In addition to the solution for the treatment plants at the CSO site, a solution for remote start of a sampler in the Hoffselva river downstream of the CSO site was also designed and installed. To log the additional on-line data, the data acquisition manager (DAQ Manager) installed on a PC with wireless internet connection using an ICE router, was extended with additional channels.

The online monitoring system has then been used also for the lamella settler once transferred to Hoffselva (WA3). For both the HRF solution and the lamella settler, data can be stored on the PC and can be transferred to other users at the project partners. Remote access to the desktop of the PC also enables remote start/stop of the plant.

2.2.1.3 Reducing CSO overflow volumes by Real Time Control

The ADESBA real-time-control (RTC) system to enhance storage of combined sewage inside the sewer network, was developed by DESSIN-partner SEGNO.

The aim of ADESBA is to utilise the total storage capacity of the wastewater network; to this aim, ADESBA needs minute by minute information of the inflows of every storage reservoirs as well as on the CSOs and water levels. During rain events the inflow to storage reservoirs is greater than the regular outflow. To avoid reservoir filling, the settings of the throttle (tanks's outflow regulator) have to be adjusted. For this, the RTC ADESBA algorithm creates an outflow "request" from a storage upstream and sends it to a storage below where it has to be checked if the volume to be transferred from above to below can be stored. The ADESBA control system will send a permission, a rejection or a suggestion, in terms of new throttle settings, back to the storage upstream. The aim is to achieve equal fill level in all tanks. In this way, RTC can reduce the volume of overflows into natural streams or avoid CSOs completely.

The RTD activities to prepare the ADESBA RTC for demonstration in WP31 were: standardization of function blocks; development of the ADESBA modules for use in process control systems; preliminary investigation of the production optimization of the encapsulated modules; and upgrade of the ADESBA Planner with a web-based online module and recalibrated function. These were delivered according to plan and enabled a successful functional testing of the software at a cluster of five CSO facilities in WP31.

2.2.2 Water Scarcity technological solutions and results

The water scarcity challenge can be tackled with innovative solutions both on the clean water and waste water side of the water cycle. Present water treatment systems are very robust, but, as a result, do not have the flexibility to deal with changes in climate, demography, water demand etc. Therefore, (waste) water reuse is highly dependent on the development and implementation of new distributed concepts based on e.g. modular systems that provide the flexibility to quickly react to (quality) requirements on the demand side.

The solutions developed in WP2.2, coordinated by KWR, include distributed reuse technologies (both modular and mobile) with focus on sewer mining technologies and Aquifer Storage and Recovery (ASR) systems to be demonstrated, with further adaptation to different water-quality injection sources, as potential sources for drinking water, agricultural or industrial water.

2.2.2.1 Distributed Reuse (AMI-enabled Sewer Mining)

Within the concept of the DESSIN project an innovative solution for urban wastewater reuse is evaluated, namely sewer-mining (SM). SM extracts wastewater from local sewers, treats it at the point of water demand and supplies local urban wastewater non-potable uses (such as urban green irrigation) while returning treatment residuals back to the sewer system for eventual treatment in the centralised wastewater treatment plant, thus eliminating the need for expensive conveyance systems. Therefore, SM is considered a decentralized technology that is closer to the circular economy concept, in that by closing the loop between waste and resource locally, wastewater becomes not 'just' a by-product of the urban wastewater system with some potential for reuse, but a resource per se, also decreasing (or eliminating) the barrier of wastewater conveying costs.

The Athens Pilot, coordinated by NTUA, brings together two emerging technologies:

- The membrane bioreactor (MBR)/ Reverse Osmosis (RO) unit which is a hybrid technological product that on the one hand employs membrane technology to treat sewage and on the other hand, in case this function fails, can operate as conventional type of WWTP. MBR and RO units are constructed as individual containers (modular) that are joined together in one containerized compact system offering ease of transportation to be deployed either individually or in combination (depending on requirements).
- Fully automated packaged treatment plants featuring membrane based, small footprint, sewer mining technologies that allow direct mining of sewage from the network, close to the point-of-use with minimum infrastructure required and low transportation costs for the effluent.

Within the framework of the DESSIN project the two concepts of SM and MBR have been joined in an effort to develop an efficient wastewater reuse system. The MBR system provides both secondary and tertiary wastewater treatment. Secondary treatment with biological nitrogen removal is achieved within the MBR system, where most of the organic matter and the suspended solids are removed. Removal of residual particulate matter requires further tertiary treatment through a filtration process, which is also incorporated within the MBR. It is also notable that the MBR system provides adequate pre-treatment for a nanofiltration or a reverse osmosis system. Such advanced membrane treatment systems may be required when dissolved constituents are present in treated wastewater in amounts that limit wastewater reuse. A report with the focus on new membrane solutions and technologies in the form of modular packaged treatment solutions (MPTS) was delivered as D22.1. The deliverable includes a benchmark study undertaken to provide rules for the optimization of the operation of the proposed membrane wastewater treatment system. Based on the results of the benchmark study, the most critical parameter on the performance of the treatment is the solids retention time (SRT). According to the benchmark study the optimum operating conditions for the MBR system can be summarized to the following:

- Minimum dissolved oxygen concentration in the bioreactor: 2 mg/L
- Minimum internal recirculation ratio: 400%
- Minimum mixed liquor suspended solids concentration in membrane tank 8 g/L
- Minimum solids retention time: 15 d

A sewer mining software and hardware platform and the required communication solutions, for collecting, processing and visualizing data of field sensors have been developed and tested at the packaged plant in KEREFYT, Sanitary Engineering Research and Development Center of EYDAP.

The System Architecture (SW and HW) has been designed with Software and Hardware components, system structure and interoperability; this also includes: design and development of interoperable sensor data layer based on Open Geospatial Consortium (OGC) suite of standards; design and development of the server-side (back–end) software application using J2EE technologies; design and development of the server-side (back–end) software application using J2EE technologies; testing of the s/w platform using "dummy" data.

The communication solutions have been designed taking account the topology of the pilot site and field sensor installation, the communication link requirements and the cost of the solution to be used; the software platform (web application) on a secure web server has been developed in order to support the link of local events to a remote management center; the sensor data layer has been integrated with the web enabled local and remote monitoring user Interface. The most interesting result/achievement is that the communication solution and the developed software platform are enabled with local and remote management capabilities and is based on standards, low cost solutions and open source implementations. The SME TELINT contributed to the collection of data from the various sensing elements (collection tools) and set up the communication and networking between the collection tools and the front-end system.

The research has also focused on the identification of potential locations for sewer mining units at city level. The study demonstrated the impact of the solution at the city-as-a-catchment scale (modelling), identified opportunities/barriers (e.g. regulation changes) and assessed the governance/policy implications of the proposed solution.

The ICT platform for distributed sewer mining (technology) was delivered as D22.2.

2.2.2.2 Aquifer storage and recovery and reverse osmosis (ASRRO)

The aim of the research performed was to increase the potential for freshwater storage, in particular in near coastal areas where saline groundwater prevents application of available technologies for temporary storage, by developing innovative well design and operation in combination with desalinisation.

In the Dutch horticulture area Westland an ASR-Reversed Osmosis (ASRRO) was installed in brackish (3700 – 4700 mg Cl/l) coastal aquifer (coarse sands, 14 m thick) to inject the rainwater surplus of 27ha of greenhouse roofs in an aquifer (23 to 37 m below ground level). The aim was to demonstrate that a sustainable and reliable freshwater supply can be obtained by combining the techniques of ASR and reversed osmosis in one system (ASRRO). A Westland ASR groundwater transport model was set up (SEAWAT) and injection/recovery schemes quantified; the optimal well configuration was also determined.

The freshwater recovery was quantified and optimized by use of Multiple Partially Penetrating Wells (MPPW), use of the Freshkeeper at the base of the freshwater bubble and by integrating the Reversed Osmosis.

The research was coordinated by KWR as collaboration between KWR and Bruine de Bruin.

The cycling of infiltration of fresh water in winter periods and the recovery of fresh water in summer periods was monitored. Monitoring results showed:

1. In the first 1,5 years of operation (December 2012 – July 2014), approximately 20% of the injected water was recovered practically unmixed.
2. Based on the hydrochemical monitoring and groundwater transport modelling, it was found that a deeper borehole of a close by ATES well (realized before the start of the pilot) caused leakage of deeper saltwater, contaminating the water recovered by the ASR system.
3. The installed Freshkeeper proved to be indispensable to attain the still relatively high RE achieved.
4. Despite the leakage of deeper saltwater, the Westland ASR-system proves to be effective to abstract different water qualities separately and attain a significantly better ASR-performance than a conventional system would achieve.

As general result, the ASRRO solution proposed can potentially boost the recovery efficiency of freshwater upon aquifer storage from 30 to 60% at the field site, making it a reliable and economically viable water supply solution. Due to local conditions, this performance was not achieved at the site.

An assessment of membrane clogging by varying redox conditions of the feedwater was performed with the following conclusions (D22.3):

1. When combining aquifer storage and recovery (ASR) and brackish water reverse osmosis (BWRO) in one integrated ASRRO-system (ASRRO), the formation of suspended fine particles in the aquifer’s pore water forms the main threat during the RO-treatment process.
2. The particles are released during injection upon aquifer freshening and presumbly also upon oxidation of Fe(II) in the target aquifer by the injected oxic rainwater. As the particles are moved to the fringe of the injected freshwater body, abstraction of water in this zone leads to membrane ‘fouling’ (experienced at BWRO-plant the Westland site).
3. No fouling was observed at the ASRRO-plant, fed by the deepest ASR well screens (ASRRO) with brackish water from below the injected freshwater.

4. Dosing $CaCl_2$ to the rainwater before injection may significantly reduce the particle formation, but needs further study.
5. Filtration of RO-feedwater before the RO-plant is a technically viable solution, but leads to a significant increase in the cost price. Regular flushing is a low-cost solution, while on the long-term, relocation of the complete abstraction to the deepest ASRRO wells seems most promising.

As a general result, the treatment of the mixture of injected rainwater and brackish groundwater is technically viable, but requires careful consideration of the abstraction depths and the RO-treatment process. Guidelines are provided based on the DESSIN research.

2.2.2.3 Increase the flexibility and resilience of Aquifer Storage and Recovery (ASR) in strategic groundwater reservoirs

The research, coordinated by CETaqua and performed in collaboration with A21, aimed at increasing the flexibility of storage in strategic groundwater reservoirs by using different types of water qualities from the drinking water treatment chain, without compromise the comply with WFD.

Exhaustive literature review of recommendations and compilation of international experiences of ASR systems and their main operative parameters was produced and results are available in deliverable D22.4A. Historical data of the sand filtered water produced has been plotted and analysed compared to quality standards and recommendations. A regional numerical flow model was set up and used to evaluate the impact assessment of ASR in terms of groundwater volume infiltrated in the aquifer and the improvements and/or impacts in groundwater quality (conservative transport). The work has been divided in two parts: (i) MODFLOW-based numerical model to simulate the impact on injected water in the local piezometric network installed for the project (4 km^2) (ii) VISUAL TRANSIN-based numerical model to simulate the impact of ASR and ASTR at regional scale (129 km^2). The review of guidelines and recommendations reported in international literature has been also applied to the Sand filtered Water (SFW) characterization. Data from 2010 to 2014 of SFW have been plotted and aggregated in ranges to evaluate the frequencies and mean values of the bulk chemistry. Total suspended solids, Modified, Turbidity, dissolved organic carbon, total organic carbon; assimilable organic carbon, E. coli and ammonium are the parameters mainly reported as clogging and pollution control in ASR injection.

A numerical model has been built to simulate the positive impacts over groundwater quality and quantity in a typical Mediterranean deltaic aquifer (based on Llobregat delta aquifer, Spain) with the objective to bring an easy visualisation tool to MAR implementers. The model takes into account the interaction between surface and groundwater.

2.2.3 Software framework for ESS valuation

The outcome of WA1 is a standardised, broadly applicable ESS methodology that can be applied to valuate ecosystem services (ESS) of water bodies and the sustainability of the proposed solutions. The aim of WP23, coordinated by DHI, was to make this methodology available in a software system that can be configured and applied to different sites and eco-systems to assist the user in valuating different ESS strategies.

Work on WP23 was completed with delivery of D23.2 (Windows installer for the ESS evaluation software) and D23.3 (user guide and documentation). The software was then used by all demo site partners to carry out the DESSIN ESS evaluation and Sustainability Assessment, as part of WA3 activities, thereby fulfilling the objective of the work package within DESSIN.

The software development was carried out according to specifications described in D23.1. The specifications were developed in cooperation with the demo site partners, as well as other partners involved in the development of the DESSIN ESS framework and Sustainability Assessment (WA1). The specifications outline how the software should look and function in order to assist users implementing the ESS framework and Sustainability Assessment.

A beta version of the software was made available to partners for testing in January 2017, and feedback from the testing was used to refine the tool and eliminate defects. Partners were also provided with a trial version of the documentation, which was also revised based on user feedback. The final version of the documentation is available as a context-sensitive help file in the software tool.

To contribute to the legacy of DESSIN, the software tool will continue to be maintained by DHI, and will be available to the public for free. Instructions for downloading and installing the software have been made visible to the general public through the DESSIN home page.

2.3 Work Area 3 - Demonstration

2.3.1 Improving water quality in a highly urbanized area (Emscher - WP31)

The Emscher demo case (Germany) aimed to demonstrate the feasibility and effect on ESS of two innovative solutions. Both were developed to mitigate the negative effects on the water quality in the Emscher river system caused by CSO events during rain. The two demonstrated solutions are:

- A cross-flow lamella settler as a solution of local treatment of CSO overflows. The lamella settler aims at reducing the particle concentrations in overflowing water. The lamella settler was developed by UFT as a container solution and was tested at a CSO facility in Castrop-Rauxel from June 2015 to May 2016.
- The ADESBA RTC system for controlling water levels in storage volumes in the sewer system. Aim is to reduce overflow volumes from CSOs. The practical application of the ADESBA-RTC has been developed by SEGNO and was implemented in Dortmund in June 2016. After a testing phase, the RTC was activated in April 2017 and data gathering was conducted until November 2017.

Two deliverables have been completed: D31.1 as a technical report on the results of the two Emscher demonstration cases and D31.2 as the evaluation of the two demo cases with regard to ESS and sustainability.

The demo activities in the Emscher river system have resulted in the following foreground:

- Cross-current lamella settler
    - The highest efficiency (i.e. reduction of TSS, TSS fine, COD and TOC) were detected at a flow rate of 10 l/s and lower. The recommended surface load is thus about 1 m/h.
    - The container starts to be efficient at an inflow concentration threshold of approximately 300 mg/L COD.
    - The efficiency ranges from 5 to 17 % for COD.
    - The maximal potential efficiency that can be reached with the lamella settler in its current setup is 37 % (TOC), 17 % (COD), 22 % (TSS fine) and 19 % (TSS).
    - The particle concentration and type is of high importance for the efficiency.
    - The efficiencies detected were scaled up from container scale to large-scale CSO, predicting overflow load reductions of 5.9 to 17.2 %.

- RTC of sewer network
    - Newly developed visualization interfaces served to monitor the RTC of the full system, i.e. the five ADESBA-controlled CSO facilities, at a glance and online at any time from the central office.
    - Furthermore, templates for raw datasets and graphical reports were developed which were populated with data of the monitored rain events.
    - The monitored overflow behavior (volume and duration) with ADESBA was compared to the overflow behavior simulated in Simba#, which calculates the situation without ADESBA. Reductions of overflow volume of up to 37.3 % were detected.
    - Furthermore, an analysis of potential was conducted for the entire sub-catchment of the WWTP Dortmund Deusen, i.e. 36 CSO facilities, simulated in Simba#. Potential reductions of overflow volume of 3.8 to 7.5 % were determined.

Both demo case solutions have been evaluated with regard to their effects on ESS. ESS are expected to be enhanced via an improvement of water quality. This means that pressures on the ecosystem are reduced via the two technologies. The lamella settler reduces the particle concentrations in overflowing water. This again reduces particle, organic cabon, nutrient and contaminant input into receiving streams. The RTC minimizes the overflow volume and frequency. Thus, in-stream flow peaks are shortened and potentially even avoided. Going along with a reduced overflow volume, a reduction of the overflow load is predicted. For both technologies, a thorough sustainability analysis has been conducted in order to appraise further criteria which have not yet been examined in the ESS assessment. Here, criteria like investment and operational costs and effort have been estimated as well as potential risks and probability of failure. Furthermore, energy consumption and compliance with the WFD have been predicted and discussed.

2.3.2 Improving water quality in a peri-urban area (Hoffselva – WP32)

The Hoffselva river (Oslo area, Norway) suffers from discharge of combined sewer overflow (CSO) during high rain events, with a negative impact on water quality and the recreational value of the area. Within DESSIN, two innovative solutions and their benefits to improve that situation were demonstrated: i) a high rate filter developed by the Norwegian company Inrigo AS (Inrigo) combined with on-line monitoring and wireless data communication supplied by the Norwegian company LKI, and ii) a cross flow lamella settler developed by the German company Umwelt- und Fluid-Technik Dr. H. Brombach GmbH (UFT), also in combination with on-line monitoring and data communication from LKI. The demo site owner at Hoffselva and the utility owning and operating the sewer system was the Water and Sanitation Agency of Oslo Municipality (VAV).

The innovative high rate filtration (HRF) system and cross-flow lamella settler (CLS) have been investigated in parallel for local treatment of CSO discharge at Hoffselva. 13 CSO events have been recorded during the demonstration period in 2017. Online Turbidity measurement and water quality lab analysis were performed to document the treatment efficiency. The demonstration results indicate that the local CSO treatment is an effective method to reduce the emission of particulate pollutants into river. Finally, the design criteria of HRF and CLS plants are proposed for CSO local treatment at Hoffselva.

On the one hand, the solutions were assessed with regard to their technical performance the direct effect on river water quality, but also with regard to their benefits and co-benefits in terms of the Ecosystem Services (ESS) provided by the river, and with regard to their sustainability.

Water samples were collected in the downstream section of Hoffselva at Skøyen, and at the inlet and outlet of the demo plants. The performances of the demo plants were also monitored on-line with sensors for turbidity and operation parameters such as relevant water levels and pressure drops. The instrumentation, data logging and communication equipment facilitated remote monitoring and control of the demo plants.

Operation of the demo plants did not have an impact on the water quality in Hoffselva. In the evaluation of ESS, a value of 252 mg SS/l has been applied as a typical peak concentration of suspended solids in the river during situations with CSO discharge before any implementation of the solutions. Similarly, a value of 8 mg SS/l has been applied as a typical concentration of suspended solids during conditions without any CSO discharge.

An estimate of the concentration during CSO discharge with distinct levels of implementation of the two solutions has been found based on the reduction in mass discharge. Several sources of uncertainty have been identified. The results, however, illustrate the importance of the storage volume. The separation technologies, i.e. the CLS and the HRF, were found to have a relatively small contribution to the total load reduction. The results also indicated that the implementation alternative, i.e. the number of CSOs where the local treatment is implemented and the risk classification of these, is of higher importance than the choice between the two solutions demonstrated in this study, i.e. implementation at many CSOs with the CLS solution will probably improve the conditions more than implementing at a few CSOs with the HRF solution despite a higher separation efficiency. As expected, the highest improvement is indicated for the implementation alternative with use of the solution with highest separation efficiency at most CSOs.

The pair-wise comparisons of results show that the differences between the two solutions are mainly related to the differences in the separation technologies, but that the overall removal for a given implementation alternative, and thereby the effect on compliance, is similar. There are also some differences in energy consumption and costs. As expected, larger differences in costs are found in the comparison between implementation alternatives irrespective of solution. The differences in overall removal and thereby also compliance, can also be expected to be larger between implementation alternatives than between solutions for a given implementation alternative.

2.3.3 Freshwater supply for horticulture from brackish aquifers (Westland – WP33)

From 2014 to 2017, a pilot was conducted at the Westland Demo site in order to integrate ASR, the Freshkeeper, and desalination in one system by consortium partners KWR Watercycle Research Institute and SME Bruijne de Bruijn, both from The Netherlands. The objective was to create a sustainable and robust freshwater supply, using the characteristics of the aquifer as an ecosystem service. This advance 'ASRRO' system must improve the freshwater recovery upon conventional ASR, while mitigating the negative impact of brackish water reverse osmosis.

The experimental activities at the Westland demo site have resulted in the following Foreground, (see also Deliverable D33.1):

- Conventional ASR in the typical Westland saline aquifer results in ASR recovery efficiencies <30%. This can increase to efficiencies >50% with the innovative well design and even more by the use of RO.
- The advanced ASRRO system showed capable of 1) enlarging the recovery of unmixed freshwater upon storage, 2) providing a more robust water supply thanks to the use of RO and 3) attaining a neutral water balance to prevent mining of water from a coastal aquifer.
- Clogging of membranes (and potentially: re-injection wells) during ASRRO appears to be driven by mobilization of clay particles and Fe-colloids. This can be mitigated by regular flushing of the RO-membranes with permeate and regular cleaning of the re-injection well.
- The impact of widespread use of ASRRO on the regional Westland groundwater system was limited based on regional groundwater modelling, but it was shown that ASRRO decreased the chloride concentration with respect to the autonomous scenario and the use of brackish water reverse osmosis (BWRO). ASRRO was successfull in mitigating the local negative impact (saltwater plume formation) caused by the deep disposal of membrane concentrate during BWRO. An overall positive to neutral impact of ASRRO on a coastal groundwater system is presumed, which is an improvement with respect to the use of BWRO in the same setting. ASRRO thus provides means to more sustainable use of coastal groundwater systems.

Deliverable D33.2 shows that application of the advanced ASRRO system creates value for three types of ecosystem services (ESS):

- Availability of groundwater for irrigation (provisioning)
- Chemical water conditions (regulation and maintenance)
- Stormwater retention (regulation and maintenance)

If only the production is considered, ASR technology makes the production of irrigation water more expensive. When environmental effects are taken into account as well, ASR becomes a more competitive option, even when measures are needed to filter out contaminants from the water that is injected. Under current policy, mitigation of environmental effects is not required, which is a reason why this technology is presently not used at most horticultural complexes in the region. Planned policy revisions (2022) may however provide opportunities for wide scale application of this technology, although subsurface spatial planning issues still need to be resolved. Further upscaling of the technology could be beneficial, especially if all groundwater abstraction is compensated for by injection of fresh water. Thus, it may potentially also reduce sea water intrusion that takes place along the coastline. At a larger scale application, complete compensation would be possible if companies with a low water demand inject more water than they abstract, to compensate for companies with a high water demand that abstract more than they inject. As such a system needs incentives; a water bank system is proposed as a measure to make the water use in the whole region more sustainable.

2.3.4 Sewer mining for urban re-use e.g. for irrigation of urban green (Athens – WP34)

A packaged plant consisting of an advanced Membrane Bioreactor coupled with ultra-filtration and reverse osmosis (MBR-RO) was installed in the EYDAP R&D department (KEREFYT);(M18 progress report). The installation, which is linked to the Metamorfosi WWTP, facilitates direct abstraction from main sewers and is able to accept multiple types of effluent (municipal and industrial). The Athens' pilot plant has been operating for more than two years, from 2015 until now (see also the previous progress reports). During the first year the operation of the unit was thoroughly examined so as, to fortify its stability and final effluent quality while in the second year the optimization of the unit with respect to several crucial parameters took place. The results from the 2 years of unit's operation underpin that:

- the installed MBR-RO pilot unit can reclaim water of excellent quality which is in line with the stringent standards that are specified in the Greek National legislation regarding wastewater reuse for unrestricted irrigation and urban reuse.
- the system presented great stability, with the effluent quality being independent of the inlet's qualitative fluctuations.

While, the optimization with respect to several parameters, such as, sludge retention time, hydraulic retention time, organic loading and the employment additives in combination with their impact assessment on the system's performance regarding the final effluent quality, GHG emissions, energy demand and membrane fouling (M36 and M48 progress reports), highlight that (M48 progress report and D34.4):

- the use of additives reduced membrane fouling –as expected- but the reduction was not radical enough to justify the entrance of additives into the maintenance protocol.
- The optimal sludge retention time (SRT) is 20 days (as designed)
- The use of additives reduced membrane fouling –as expected- but the reduction was not radical enough to justify the entrance of additives into the maintenance protocol.

Furthermore, during the M36 reporting period, the monitoring and supervisory system of the unit has been fully developed, installed, tested and implemented. Subsequently, until M48 progress report its features has been improved and extended. The integrated SW and HW platform is collecting, processing and visualizing data collected from the field sensors installed at the pilot area. The front-end and back-end of the ICT/Monitoring solution (also referred as Advanced Monitoring Infrastructure; AMI) have been implemented using a low-cost solution (small sized single board computer), adopting OGC standards supporting interoperability. The final solution offers a user-friendly cloud-based User Interface which are in accordance to modern computing development standards.

Finally, we conducted an economic analysis and evaluation of ESS. Its three main pillars are: (a) the estimation of water scarcity mitigation, (b) the valuation of water-enhanced ecosystem services (microclimate regulation) and (c) a discussion on derived economic activities as well as the business model for the sewer mining unit's sustainable operation in a market environment (see D34.3). Its main results are (see M48 progress report and D34.3):

- Microclimate regulation benefits for a model household of 4 people (parents and 2 children) range between € 130-180 annually, depending on the sewer-mining unit's technology (MBR-UV or MBR-UV-RO).
- Groundwater scarcity cost mitigation ranges between € 0.40-0.50/m3, depending on the sewer-mining unit's technology (MBR-UV or MBR-UV-RO) and the cost reduction rate (learning curve) per year. Specifically, this is achieved for an average total cost reduction rate of the sewer-mining unit ranging from € 0.08-0.09/m3/year so that within the first five (5) years the major part of the scarcity cost will have been mitigated by both technologies.

2.3.5 A flexible ASR system to recharge different water qualities (Llobregat - WP35)

The experimental activities at the demo site in the Llobregat have resulted in the following Foreground:

- Validation of sand filtered water as a pre-potable water type to be injected in Llobregat Delta aquifer
    - Beginning with a preliminary study of sand filtered water characterization and a comparison with legal limits and international experience, continuing with a pilot column test and finishing with the injection in a real well, it was validated the suitability of sand filtered water of Sant Joan Despí Drinking Water Treatment Plant as injecting water in Llobregat Aquifer Storage and Recovery system.

- Demonstration of the benefits of pre-potable water aquifer injection
  - After the conditioning of existing network of observation wells and implementation of additional piping , during one year period it was injected a total of 0,6 Hm^3 of sand filtered water and it were monitored groundwater parameters (both physical and chemical) to study all the injection impacts.
  - The advanced hydrogeochemical modelling of different scenarios, including demonstration phase (with calibration with real data) and full-scale implementation, allowed to demonstrate the impact of the recharge and served for ecosystem services evaluation
- Validation from ASR operator and administration of the applicability of the demonstrated innovation
  - Working side by side with the ASR operator (Aigües de Barcelona) and reaching agreements of the research plan with the administration, allowed the applicability of the results and its future transferability to a full-scale implementation
- Introduction of the concept of Managed Aquifer Safety plans as a methodology to be applicable to flexible ASR systems to other European sites
  - With the experience gained in the demonstration phase and during the knowledge and results transfer to water administration and public health agency, it was developed as a preliminary concept, a methodology
- ESS application in demo site
  - It were assessed the beneficial effects of ASR technique in terms of ESS enhancement and it was studied the economic approach to include these services in a regulated payment system.

2.4 Work Area 4 – Bringing Innovation to Society and Market

Work Area 4 was mainly focused on developing public project correspondence and dissemination materials, establishing showcases at all demo-sites and maximising the market reach and impact of the solutions developed in WA1 and WA2 and demonstrated in WA3.

All the planned materials and tasks have been successfully developed and, in addition, extra materials have also been produced. These materials have served to reach all the defined objectives and to bring the innovation and the key results of the project to Society and Market, which was one of the main aims of this area.

2.4.1 Dissemination of DESSIN and development of its demo-sites as showcases (WP41)

All the promotional contents and dissemination materials produced within DESSIN are explained in detail in Deliverable D41.3.

Regarding Work Package 41, its key outcomes are:

2.4.1.1 Website news

The DESSIN website, developed within Task 41.2 (www.dessin-project.eu) serves as an information source for the DESSIN project and as a principal outlet of informational products about or coming from DESSIN, such as deliverables or the DESSIN newsletter and magazine.

The news section has been updated during the lifetime of the project with 94 posts, including interviews, deliverables, dissemination materials and achievements from the project or new milestones reached. This continuously updated blog on the DESSIN website (at least once a month) has served to keep the DESSIN external audiences informed about the project progress. Regarding the downloads section, it has been used to store different materials, such as DESSIN results, dissemination materials or the DESSIN Ecosystem Services Valuation Toolkit, among others.

Besides, an internal area was set up for the DESSIN members (internal audiences) to allow them to share their work in progress, and to be able to receive minutes, presentations, project templates, internal documents, among other things.

Apart from the website, during the lifetime of the project different promotional contents and dissemination materials have been produced:

2.4.1.2 Newsletter

The electronic newsletter is an online dissemination material that has served to communicate general information related to the project's demo-sites, the faces behind the project, the main progress of DESSIN and its most relevant milestones. During the lifetime of the project, 6 issues of the newsletter have been produced and sent both to the project consortium and to the newsletter's subscribers, previously registered through DESSIN website.

All the newsletters have followed the same structure, sorted in 6 sections: Our demo sites, Interview, Success Story, ESS Section, DESSIN Marketplace, DESSIN achievements and Upcoming events.

2.4.1.3 Leaflet

As part of additional material not included in the proposal, WA4 produced a leaflet explaining the main points of the project. It is focused on offering a general overview of the project's context, objectives and the demo-sites, in order to serve as an informative material to discover DESSIN in general.

2.4.1.4 Annual Magazine

The Annual Magazine is an online material (can also be printed) explaining the progress and works of the project, without a regular structure. Nevertheless, each issue includes an interview to a relevant person related to the project and/or to ESS, the last news on the project, information about the ESS Evaluation Framework and the project partners. During the lifetime of the project, 4 issues of the Annual Magazine have been produced (2015, 2016, 2017 and Final Magazine). The Annual Magazine 2015 and 2016 were printed and distributed among the partners.

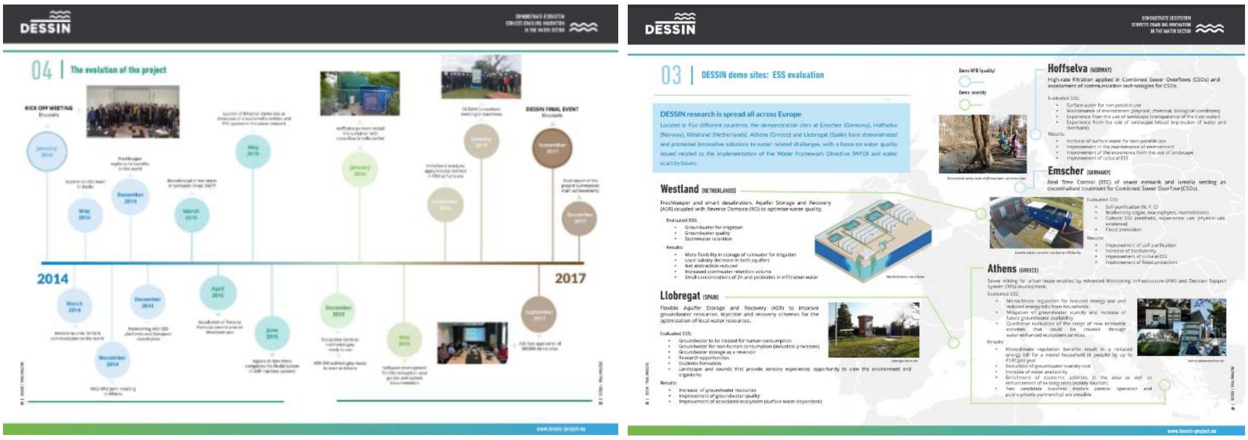

Figure 2 DESSIN final magazine

Besides, we published an additional issue of the Annual Magazine during the last month of the project. The so called Final Magazine is an online and printed material based on the Annual Magazine that gives an overview of the project context, objectives, the ESS Evaluation Framework and includes an explanation of the five demo-sites and its main results referring to Ecosystem Services. It has been used for the final dissemination of the project to interested audiences and different stakeholders. In this case, 1.250 copies of the Final Magazine were printed and sent among the partners, in order to be distributed among partners' stakeholders and interested groups. This issue was also delivered to the attendants of the DESSIN Final Workshop, held in Brussels on November 28th 2017 and the local workshop held in Barcelona on December 12th 2017.

2.4.1.5 ESS Evaluation Framework brochure

The ESS Evaluation Framework brochure was developed in order to explain the Ecosystem Services Evaluation Framework created by WA1. This material helps to draw the whole picture of the framework, especially to non-especialised audiences. The brochure was printed and delivered among the project partners and the attendants to the DESSIN Final Workshop.

2.4.1.6 Press release

A press release on ESS Evalutarion Framework was sent to different media channels in order to inform on the creation of the ESS Evaluation Framework.

2.4.1.7 Final Video

The DESSIN video is the main material for future dissemination. It was produced during the last months of the project and serves to show the context, the objectives and the research developed within the project, as the ESS concept and the ESS Evaluation Framework, to a general and non-specialised audience. Two versions of the video were produced:

- **Long version**: this version includes an explanation of the solution demonstrated at each demo-site and the main results obtained.

- **Short version:** the short version only offers a general overview of the project context, objectives and main results. This version has been produced for online distribution through online channels, such as social media.


Figure 3 Frames from the DESSIN video

2.4.1.8 Re-usable illustrations

A pack of re-usable illustrations has been produced to help disseminating the project. Those images and graphics serve to ease the comprehension of some of the DESSIN technologies, systems and processes and can be used in different types of communication and dissemination materials, both printed and online.

2.4.1.9 Policy Briefs

DESSIN produced a set of policy briefs in collaboration between WP12 and WP41. These briefs provide a series of five recommendations on governance design factors conducive to innovation uptake. Both are targeted to water managers and policy makers, aiming to create enabling environments for innovation uptake.

Those documents are available in DESSIN website:

- DESSIN Policy Brief #1: Good Practice in Urban Water Management: Designing governance and financing regimes to encourage innovation uptake.
- DESSIN Policy Brief #2: Good Practice in Urban Water Management: Increasing chances of innovation uptake through governance.

2.4.1.10 Showcases

Regarding Task 41.4, during the lifetime of the project, in each of the DESSIN demonstration sites showcases have been successfully developed and established. Each showcase was set up in a distinct way, reflecting the local conditions, target audiences and wishes. The overall objective of the showcases is to promote the uptake of the innovative solutions enhancing ecosystem service, developed in DESSIN, and show relevant stakeholders, authorities, decision makers, researchers and the general public their potential. The showcases also provide a playground for new technologies to be demonstrated in a real life environment. The showcases had a clear role during the DESSIN project, but we also foresee active showcases beyond the DESSIN lifetime to endorse the uptake of the innovative solutions. In Deliverable D41.4, the established showcases at demo-sites are explained in detail.

The **Emscher** showcase consists of three movies describing how innovative technological solutions help improve ecosystem service provision in dense urban areas. The three movies focus on (1) the Emscher area and its reconversion and restoration process going along with water quality challenges, (2) the demonstration of a decentral treatment of combined sewer overflow via a lamella settler solution, and (3) the demonstration of a Real Time Control system via the ADESBA solution.

The **Westland** demonstration site was developed into a fully functioning showcase. The showcase includes a guided tour along the different objects of the facilities at the demo site, a mobile banner exposition of the different technologies applied at the site, and also promotes and enables testing of innovative technologies, equipment and methodologies. The Westland showcase is located within the facilities of the Prominent Innovation Centre in Gravezande in the Westland, the large greenhouse area between the cities of The Hague and Rotterdam (Greenport Westland). This showcase also consists of a video explaining the solutions tested and developed in this demo-site.

The **Hoffselva** showcase consists of the demonstration site (inlcuding information boards) and activities and means for spreading information about the technologies, the ESS evaluation and the DESSIN project, and dissemination of results from the demonstrations. This showcase also consists of a movie explaining the demo-site and the demonstrated solutions in Hoffselva river within DESSIN.

The **Athens** showcase acts as demo facility for water innovations. The Athens showcase supports on-site visits, by developing an information board, leaflets, targeted presentations and a dedicated website, as well as dissemination material including an animated movie showing the concept and benefits of sewer mining to potential target groups.

The demo site at **Llobregat** is located at the drinking water treatment plant (DWTP) facilities Sant Joan Despí and is easily accessible for all visitors of the water company, which supports the development of a DESSIN showcase. The showcase includes a.o. a notice board, a digital totem, on-site visits and an animated movie explaining the concept of pre-potable water injection into aquifers.

2.4.2 Route to Market (WP42)

The overall objective of Work Package 42 was to maximise the market reach and impact of innovative water technologies developed in work area one and two and demonstrated in work area three. As part of this *commercialisation process*, a sample commercialisation approach for innovative water technologies that relate to water-based ESSs was devised. The process comprised the following key results:

1) **Business Environment Analysis (D42.3):** DESSIN's commercialisation activities were commenced with an assessment of the business environment in the form of two *outside-in* reports which consider the wider market picture and determine opportunities and market risks for ESS-related innovations in the water sector. Both reports provide a wider market

overview for innovations linked to water quality-related ESSs and analyse the general market for the respective DESSIN solution package.

a) Report on water scarcity (Llobregat, Spain)
b) Report on water quality (Emscher, Germany)

2) **Market analysis (D42.1):** Individual customised reports for SMEs (SME point of view) with recommendations on how to enter a specific market. The documents serve as a guidance document for SMEs.
3) **Monitoring and Evaluation Platform (D42.5):** For keeping track of both, supporting and impeding conditions for commercialisation of innovative technologies that improve water-related ESSs. The M&E system is an indicator-based tool for a rapid preliminary multi-dimensional market assessment and follows a three step approach on (1) product readiness, (2) potential target markets and (3) external framework conditions (e.g. general market conditions, governance frameworks and finance). Based on the assessment, a suitability ranking of prospective target markets is created and the most promising market highlighted. The assessment thus fosters the update of ESS-relevant innovations by providing a tangible tool for SMEs that is publicly accessible via https://dessin.adelphi.de/
4) **Capacity Building and Training of SMEs (D42.2 plus 6 workshops):** Various capacity building and training activities were conducted in order to provide individual support to DESSIN SMEs. Core of the capacity building and training activities were customised training workshops during which sample runs of the commercialisation strategies were discussed with each SME. Finally, all DESSIN SMEs were brought together for a peer-to-peer learning workshop.
5) **Lobbying for ESSs valuation and assessment of modes of interaction:** ESSs valuation as promoted among various stakeholders and decision makers in the water sector (participation in conferences and organisation of several workshops).
6) **Promotion of Innovations Based on water-related ESS:** SMEs were brought together and were jointly represented at existing dialogue forums e.g. EIP action groups, WssTp and ERRIN in order to foster an enabling business environment. ESSs lobbying was continued through promotion of DESSIN solutions among policy makers and prospective end-users at a national and international level.
7) **Strategy paper (D42.4):** Based on the previously explained activities and results, a strategy was prepared that covers aspects pertaining to the marketization of the proposed ESS valuation methodology within the European Union (with a particular focus on Germany and the Netherlands).

3 Potential impact, dissemination & exploitation of results

3.1 Overview

At all demonstration sites, follow-up activities are in full swing. They are very diverse in nature and extent, but range from continued testing to full-scale implementation, replication and even regional roll-out. More details are given in sections 3.2 to 3.5, but here is a summary of some highlights:

- The DESSIN team has published the ESS evaluation framework in a key journal for of the "Ecosystem Services" scientific community.
- Beneficiaries who have branches active in consulting (such as Ecologic, IWW, adelphi) will use the ESS valuation methodology in their consulting services for the water sector, to facilitate cost-benefit analysis and enable better and more transparent decision-making.
- Beneficiary DHI has transformed the ESS framework into a software module that is now part of an overarching software suite (MIKE) offered by DHI internationally. DHI will further pursue the commercialization. Whilst the basic (and fully functional) version of the software is freely available, there will also be an extended version with additional features such as an indicator manager and the ability to run simulation models within the tool.
- Beneficiary UFT has already started a commercial follow-up of the lamella settler solution from WP21/WP31: a cross-flow settler built in Eutingen (Southern Germany).
- Beneficiary SEGNO is aiming to build a reference business case with ADESBA. To this aim, SEGNO has already held a joint workshop with the case owner, Emschergenossenschaft. The priority will be to first approach the German-speaking countries where references with existing regulations and guidelines are already tested and known. Afterwards, SEGNO aims at approaching the rest of the European market.
- Beneficiary Inrigo is currently promoting the first installation of man-hole type high rate filtration (HRF) system (WP21/WP32) in one of the several Norwegian municipalities who showed interest in this technology for local CSO control.
- Demonstration of the effects and costs of ASRRO at the Westland site has supported convincing other individual greenhouse owners to implement ASR or ASRRO on their plots: around 11 ASRRO wells have been built since 2015 and around 12 are in the final design phase, which will result in an estimated turn-over for SME's of over 3.0 M€. Beneficiary KWR and Dutch engineering consultant Arcadis have set-up a Public-Private Partnership (Allied Waters, Collab SALutions) to bring the knowledge to market (staffed by 2-3 fte in 2018).
- The sewer mining solution from Athens (WP34) has won a European Business Award; the demonstration will run at least one more year beyond DESSIN. Replication has started by installment of a similar unit in the *Natura* protected area of Schinias, Greece; the installation of a full-scale unit in an urban area of Elaionas has been authorized.
- Linked third party Aigües de Barcelona (demo site owner) is willing to apply the Aquifer Storage and Recovery system from WP35 in real scale in 2020/2021, when the facility will be prepared and the public authorities have granted the permit.

- All sites have been transformed into local showcases, some with a focus on educational material (e.g. videos), others even with walkable routes among the installation, permanent information boards and local on-site events with pupils, students, and other target groups.

3.2 The Ecosystem Services Evaluation Framework (WA 1)

Results from Work Area 1 have been and continue to be disseminated through various external channels since early on in the project. These include scientific publications like *Getting into the water with the Ecosystem Services Approach: the DESSIN ESS Evaluation Framework* by Anzaldua et al., published open access in the Elsevier “Ecosystem Services” journal in 2018; *Governance Regime Factors Conducive to Innovation Uptake in Urban Water Management: Experiences from Europe* by Rouillard et al., published open access in the MDPI journal “Water” in 2016; and *Large-scale river restoration pays off: A case study of ecosystem service valuation for the Emscher restoration generation project* by Gerner et al., submitted to the Elsevier “Ecosystem Services” journal in 2017; among others. Outputs have also been showcased in a dedicated post in The Freshwater blog (www.freshwaterblog.net) as well as presentations and sessions in conferences inter alia the *European Ecosystem Services Conference* in Antwerp, BE in 2016 and the *Nature based solutions & Urban Agenda Conference* in Utrecht, NL also in 2016. Regarding the outreach to the industry and practicioners community the results from Work Area 1 have been presented in the technical publication *Promoting Innovation Through The Assessment Of Changes In Fresh Water Ecosystem Services: The DESSIN ESS Evaluation Framework* by Anzaldua et al., published in the German American Water Technology Magazine in 2015; at the yearly European Innovation Partnership on Water event in Leeuwarden, NL in 2016 and in a dedicated webinar for the Ecosystem Services Working Group of the WssTP in 2016. Internal exploitation of the results was ensured through the design of the project’s work plan (e.g. application of the DESSIN ESS Evaluation Framework on the demo sites) and was actively pursued beyond the project via collaborations with other European Research projects like OpenNESS, MARS, AQUACROSS and SHEBA, through implementation of the ESS framework in several PhD studies and its inclusion as a key element in new European research project proposals.

The potential policy applications of the DESSIN ESS Evaluation Framework as a tested integrative assessment are various and particularly relevant for the revision of the WFD, for instance to inform the design of new status indicators suitable for the evaluation of WFD Programmes of Measures. Further, the Work Area 1 team is exploring the link between ESS and the Sustainable Development Goals (SDGs) with the aim of framing DESSIN ESS evaluation results under the objectives of inter alia SDG6: *Ensure availability and sustainable management of water and sanitation for all,* SDG8: *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all,* and SDG12: *Ensure sustainable consumption and production patterns.* As stated earlier, the results from ESS evaluations using the DESSIN framework have great potential to supplement large EU-scale ESS assessments and be taken up by e.g. WG MAES, particularly for the ex-post assessment of management options for ecosystem restoration and biodiversity protection and conservation.

3.3 Technology solutions developed (WA 2)

3.3.1 Water quality technologies (WP21)

3.3.1.1 Enhancing treatment efficiency in CSO holding tanks with cross-flow lamella settlers (WP21.1)

Beneficiary UFT has already started a commercial follow-up of the lamella settler solution from WP21/WP31: it has further developed the cross-flow lamella settler type used in DESSIN and now introduced it to the market. UFT has now built a commercial full-scale plant in Eutingen (Southern Germany). Hence, this is a good example of a replication and trans-regional transfer of a solution demonstrated in DESSIN and taken to the next level of commercialisation by the beneficiary, a SME.

3.3.1.2 Local treatment of CSO overflow by High Rate Filtration (WP21.2)

The potential value of reduced discharges from CSO for beneficiaries is substantial. It relates both to Regulation & Maintenance and to Cultural ESS. Considering the direct effects of the demonstrated solutions, the Cultural ESS associated with aesthetic appreciation of the river water itself and riverbank area, *i.e.* ESS associated to transparency of the river water, and visual impression of water and riverbank, were selected as Final ESS. Inrigo is currently promoting the first installation of man-hole type high rate filtration (HRF) system in one of the several Norwegian municipalities who showed interest in this technology for local CSO control.

3.3.1.3 Reducing CSO overflow volumes by Real Time Control (WP21.4)

The first priority of SEGNO after DESSIN is to build a reference business case with ADESBA. To this aim, SEGNO has already held a joint workshop with the case owner, Emscher Genossenschaft. The aim is to roll out ADESBA in the area of Emscher and use the business case for further marketing campaigns. The priority will be to first approach the German-speaking countries where references with existing regulations and guidelines are already tested and known. Afterwards, SEGNO aims at approaching the rest of the European market.

3.3.2 Water scarcity technologies (WP22)

3.3.2.1 Distributed reuse through sewer-mining in large urban areas (WP21.1)

The DESSIN's Athens pilot developed and demonstrated an innovative decentralized and modular solution for urban water use. The solution consists of a compact sewer mining (SM) unit enabled by advanced monitoring infrastructure. The results obtained from the pilot indicate the potential of the technology to provide reclaimed water at low-cost (0.86-1.07€/m3) and simultaneously reliably meet all the national and international criteria set for all types of non-potable wastewater reuse. The solution has won EYDAP and its partner institutions (the Athens' water supply and sewage company - and a project partner) two awards in the European Business Awards for the Environment (EBAE) in two categories the Products & Services and the Business & Biodiversity. As a follow up to this, EYDAP, with the support of its partner institution NTUA, decided to prolong the operation of the Athens pilot for at least one more year aiming at conducting further piloting to assist upscaling and promote full scale applications. Finally, the Athens solution has triggered further innovation development, as it allowed NTUA to obtain the permit to install a similar unit in the *Natura* protected area of Schinias, Greece. It also motivated the municipality of Athens to participate in a new H2020 project, called *NextGen* and authorize the installation of a full-scale SM unit in the urban area of Elaionas, Athens, Greece.

3.3.2.2 ASRRO for saline or brackish aquifers (WP22.2)

Based on the results of WP22.1, the potential, essential guidelines, and pitfalls for the use of ASRRO were quantified. The impact of this is that in current application of aquifer storage and recovery, the optimal set-up of the ASRRO based on the Westland site is taken up in the design phase and in the regional planning of water supply measures.

Two most relevant examples:

- The Glasparel+ area: around 100 hectares of greenhouses currently under development in the Waddinxveen area. The basis of their water supply was mend to be aquifer storage and recovery (ASR) of local rainwater in a brackish aquifer. However, in dry years, ASR was predicted to be insufficient. During the final design phase, the ASR was transformed to ASRRO with approval by authorities. The construction phase is planned for 2018 and results in a turn-over for SMEs (construction and engineering firms) of around 2.0 Me;
- The ASRRO is considered a solution on the regional scale of the Westland area. In this set-up, ASR and RO are combined over the whole extent of the Westland area in order to balance freshwater abstraction and replenishment of the aquifer, while maintaining the guarantee of a high quality freshwater source (thanks to RO-treatment) and complying with groundwater quality aims. This was supported by the modelling performed in WP33. The estimated resulting turn-over for SME's for realizing these regional adaption strategy using ASRRO is more than 29.0 Me.

3.3.2.3 Increased flexibility and resilience of Aquifer Storage and Recovery in strategic groundwater reservoirs (WP22.3)

Amphos 21 has contributed to WA 2 of DESSIN by developing a software tool to evaluate all water interactions when applying a MAR system in a typical and generic coastal deltaic aquifer. The aim was to provide a tool to quantify the impacts of the technique in a general view and to help to overcome implementation barriers related to the difficulty of showing the benefits of the technology to non-experts. At the same time these impacts could be related with ESS changes and quantified using economic valuation.

As result from the modelling results and consequent demonstration, the local authorities are motivated to further study the potential of full scale application of pre-potable water injection schemes to secure water supply

3.3.3 Software framework for ESS valuation (WP23)

The DESSIN software tool developed to assist with implementation of the DESSIN ESS evaluation framework and sustainability assessment developed in WP23 provides water utilities with additional inputs to the traditional evaluations of alternatives solutions. It enhances the capability to distinguish the most effective and efficient solutions as more informed decision making and in turn promote innovation and competitiveness in the water sector because it provides economic arguments for the implementation of innovative solutions.

The software tool will continue to be available to the public after the conclusion of the project. DHI will support the tool and will make it available for free as part of its MIKE OPERATIONS software package. DHI hope that others outside the DESSIN consortium will use the tool to support ESS assessments and integrate ESS values into the cost-benefit analysis of proposed projects and measures.

3.4 Demonstrated solutions (WA 3)

The key aspects regarding (potential) impacts, dissemination and exploitation from the DESSIN demonstrations are closely related to those outlined for WA 2 in chapter 3.3, because these two Work Areas were forming a logical sequence: RTD activities in WA 2 prepared and supported the actual demonstration of technologies in the real environment settings of WA 3. However, the actual demonstration of the solutions and the assessment of their benefits and co-benefits (through the ESS evaluation framework developed in WA 1) yield a more detailed and specific perspective.

The key features with a high potential impact from WA3 are as follows (for more details see sections 3.4.1 to 3.4.5):

- Emscher demonstration (WP31): Potential for application of demonstrated innovative technologies (lamella settler, RTC) by the water boards Emschergenossenschaft and Lippeverband, especially to adapt existing water infrastructures to climatic and demographic changes in the future. Continuation of ongoing ADESBA-RTC operation and potential for extention by including further CSO facilities into the RTC system.
- Hoffselva demonstration (WP 32): Potential for application of proven innovative technologies (HRF, CLS) by water utilities (Oslo VAV) to adapt their water infrastructures to climatic and other future changes.
- Westland demonstration (WP33): Successful replication of ASRRO on other sites to secure high quality freshwater supply has created business opportunities for SMEs; setup of PPP with KWR as partner aims to stimulate large scale application of subsurface water solutions in coastal regions worldwide.
- Athens demonstration (WP34): Upscaling of the sewer mining demonstration into full scale, “real-world” applications is foreseen through active co-operation between the water utility (EYDAP) and NTUA. This may potentially result in business opportunities for SMEs providing technologies as well as services.
- Llobregat demonstration (WP35): positive decision taken by water utility and local authorites to further study the potential of full scale application of pre-potable water injection schemes to secure water supply.

3.4.1 Improving water quality in a highly urbanized area (Emscher – WP31)

A reduction of combined sewer discharges from CSO facilities is of great benefit for the water boards Emschergenossenschaft and Lippeverband who are managing the river basins of Emscher and Lippe river. As demonstrated and disussed, the two tested technologies have the potential to improve both Regulation & Maintenance and Cultural ESS. Especially for adaptation of existing water infrastructure and planning of new facilities with regard to future challenges (climatic and demographic), the DESSIN ESS and SA approaches can extend the scope of the current practice of evaluations of alternatives.

EG, with the support of its partner institution SEGNO, plans to further engage in the RTC technology implemented in DESSIN. It is planned to continue the operation of the Emscher RTC pilot for at least one more year, conducting further research regarding its efficiency and upscaling to sub-basin level. Similarly, it is planned to identify a possible second pilot site for testing the cross-flow lamella settler using different combined sewage with different types of particles, as the efficiency results obtained in DESSIN need to be validated at an additional site with distinct sewage conditions. This is to be conducted with support of our partner UFT and with the aim of future full-scale application in suitable existing or planned CSO facilities in which particle concentration needs to be minimized.

To disseminate the two demonstrated technologies, three short movies have been developed: a general movie on the challenge of CSO concerning water quality, a movie on the cross-flow lamella settler solution and a movie on the ADESBA RTC solution. The movies have been placed in the EG, UFT and SEGNO websites and are available for presentation at fairs and meetings. Furthermore, a large number of presentations has been given at EG internal, regional, national and international conferences and meetings, disseminating the DESSIN results.

The DESSIN ESS framework and the SA represent tools that can be applied to evaluate options of measures and decide for the best alternative in terms of ESS and sustainability. A simplified SA is already in use for important decisions at Emschergenossenschaft. Furthermore, the benefit assessed in the ESS evaluation of the Emscher reconversion is already widely used and presented at EG internal and external meetings.

3.4.2 Improving water quality in a peri-urban area (Hoffselva – WP32)

The potential value of reduced discharges from CSO for beneficiaries is substantial. It relates both to Regulation & Maintenance and to Cultural ESS. Considering the direct effects of the demonstrated solutions, the Cultural ESS associated with aesthetic appreciation of the river water itself and riverbank area, i.e. ESS associated to transparency of the river water, and visual impression of water and riverbank, were selected as Final ESS.

The solutions demonstrated in DESSIN may be additions to the 'toolbox' of alternative measures that Oslo VAV may use in assessing options for future adaptation of the water infrastructure, and the DESSIN ESS and SA methodologies may give additional inputs to the traditional evaluations of alternatives.

3.4.3 Freshwater supply for horticulture from brackish aquifers (Westland – WP33)

Thanks to the transformation of the Westland Demo site to a showcase (including information panels, accessibility, scale models, information video), over 500 people from over 20 different countries visited the Westland demo site during the DESSIN lifetime. Since then, several initiatives have taken off to store different water sources in similar ways, such as treated waste water (reuse), urban stormwater (Rotterdam), surface water, and drainage water.

Demonstration of the effects and costs of ASRRO at the Westland site has supported convincing other individual greenhouse owners to implement ASR or ASRRO on their plots: around 11 ASRRO wells have been built since 2015 and around 12 are in the final design phase, which will result in an estimated turn-over for SME's of over 3.0 M€.

Inspired by the succes of ASRRO as an example of a subsurface water solution, KWR and Dutch engineering consultant Arcadis have set-up a Public-Private Partnership (Allied Waters, Collab SALutions) to bring the knowledge to market. By 2018, this collab is staffed by 2-3 fte.

3.4.4 Sewer mining for urban re-use e.g. for irrigation of urban green (Athens – WP34)

The experimental results from the Athens demonstration: Sewer Mining for Urban Re-use enabled byAdvanced Monitoring Infrastructure (AMI), indicate that the implementation of an on-site compact treatment system consisting of a pre-treatment unit followed by a membrane bioreactor and finally a UV unit for disinfection can reliably meet all the national and international criteria set for all types of non-potable wastewater reuse (see D34.3). This in combination with the AMI facilitates a novel decentralized, modular and economically-feasible solution for water recovery for non-potable uses. Undoubtedly, this innovative solution paves the way for large-scale low footprint, water reuse adaptation, thus saving fresh water, in highly urbanized, space-limited environments (objectives in accordance to DOW).

Building on the conducted economic evaluation and the identified scale-dependent business models for the optimal diffusion and operation of the sewer-mining technology in a market environment it can be argued that the public-private partnership model can be considered to be more flexible for both the small and the large-scale (see D34.3). Nevertheless, irrespective of the business model selection and the area's scale, it is expected that in any case the increase of water availability due to the installation of a sewer-mining unit could lead to significant enrichment of economic activities in the area as well as enhancement of existing ones. The majority of these new activities could relate to tourism (eg. for the Athens case, increased number of arrivals due to the upgrade of "green" environmental state, more visits to a nearby archaeological site, environmental education activities, small-scale bio-culture and generally better value-for-money per unit of visit).

According to the above elements, a major potential for the commercial diffusion of the sewer-mining technology is the creation of local markets. In particular, these markets can take the form of real-time or programmed contract-based exchanges of recycled water or useful materials for stakeholders. This prospect becomes of higher importance as the scale of the area increases and more stakeholders are involved, making the need for an organized information system on supply and demand more critical.

As far as future exploitation and exploitation of the results obtained through DESSIN, EYDAP, with the support of its partner institution NTUA, plans to further engage in the technologies implemented in the projectand thus support the operation of the Athens pilot plant for at least one more year aiming at conducting further research regarding its upscaling uptake for full scale, “real-world” applications. Furthermore, during this period more dissemination activities will be realized through workshops and meetings with other stakeholders, e.g. municipal water supply and sewage companies. Moreover, an additional plan aims at utilizing the effluent water in to the direction of upgrading the current R&D facilities into a low footprint, “green” establishment, propagating in this way the potential of the unit in making a step towards a sustainable, circular economy.

3.4.5 A flexible ASR system to recharge different water qualities (Llobregat – WP35)

Main achievement of DESSIN was the acceptance of the applied technology by the facility operator (Aigües de Barcelona) and administration authority (Water Catalan Agency). This has resulted in a willingness to implement injection of pre-potable water at full scale; From 2020/2021 onwards potentially 15 Hm^3/year of pre-potable water can be injected, reducing costs by around 1M€/year with respect to previous potable water injection.

3.5 Bringing Innovation to Society and Market (WA 4)

Work Area 4 did not produce results with a potential impact of its own, we rather designed it as a support module to bundle and facilitate project activities related to dissemination, exploitation and route to market.

3.5.1 Dissemination of DESSIN and development of its demo-sites as showcases (WP41)

Regarding the dissemination of DESSIN, the materials produced by WP41 serve to communicate the project results to target audiences and maximize its impact. The maintenance of DESSIN website is key to keep updating the interested audiences with news on the project outcomes and results, dissemination activities and future applications.

On the other hand, the distribution of online and printed communication materials, such as the DESSIN leaflet, the Final Magazine or the ESS Evaluation Framework Brochure helps to disseminate general information on the project and its main results, mainly focused on Ecosystem Services, to target audiences, such as local stakeholders, administration or decision makers.

Likewise, DESSIN Final Videos, both long and short versions, are one of the most relevant dissemination outcomes, as they compile all the information related to the project and offer a general overview on the project objectives, progress and results. Their online distribution is a powerful way to reach different types of audiences, including general public, in order to raise the awareness on the concept of Ecosystem Services.

Finally, the established showcases serve to promote the uptake of the innovative solutions enhancing ecosystem service, developed in DESSIN, and show different audiences, such as relevant stakeholders, authorities, decision makers, researchers and the general public their potential.

3.5.2 Route to Market (WP42)

Work package 42 maximised the market reach and impact of innovative water technologies by addressing two specific aspects namely the demand for innovative water technologies as well as the capacity of SMEs to serve the demand.

Demand was stimulated by extensive promotion of DESSIN technologies on international conferences as well as workshops with important decision makers from the water sector. On the other hand, adelphi capacitated small SMEs from the water sector to identify and react to demand and generate business opportunities through the application of sustainable technologies that are based on ecosystem services. Adelphi’s key capacity building efforts were SME workshops as well as the creation of an online platform to assess and rank various countries for introduction of innovative water technologies. The online *Monitoring and Evaluation* platform is freely accessible and has been disseminated and promoted on international conferences and workshops.

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