ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

Accompanying document to

Deliverable 1.2

Operational demo cases

Disclaimer: This deliverable has not yet been approved by the European Commission and should be seen as draft!

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Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
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CO = Confidential, only for members of the consortium (including the Commission Services)

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0.2	02.05.2022	J. van den Broeke	Feedback internal review
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Executive Summary

The European industry is the largest water consuming sector after agriculture, with a significantly larger water footprint than residential/urban areas. They also face a fierce competition worldwide, with limited domestic resources. Moving to a circular economy (CE) paradigm that valorises a wide range of water-embedded resources: water, energy, nutrients and high added-value compounds, will future-proof European industries, climate-proof European society and safeguard the environment. Water Smart Industrial Symbiosis (WSIS) as a particular form of CE applicable to industrial contexts promises a new potential by systematically looking to reuse wastes between industries as raw materials. WSIS promises benefits from lower costs as well as new types of revenues, exploiting 'waste' management not only as a legal obligation but as a new business opportunity.
WSIS is a novel approach with as of yet limited applications. In ULTIMATE, WSIS between the industrial sector and service providers of the water sector are demonstrated at significant scales thus creating an evidence-based approach for successful WSIS implementation anchored on real-world cases.
Therefore, at nine case studies distributed across Europe and Israel, the ULTIMATE consortium has established so called WSISs. They develop and demonstrate 21 pilot plants, which recover water, materials and/or energy.

Deliverable D1.2 is a demonstrator type deliverable and shall show, that the ULTIMATE pilot plants are operational. Therefore, presentations showing the operational pilot plants will be accessible on the ULTIMATE webpage at the case study section (https://ultimatewater.eu/demonstration-cases/). This document accompanies the presentations which are meant to be the main evidence for D1.2 and shows the progress until M24.

Prior to the pilot plant implementation, eight WSISs conduct laboratory experiments. In total, 15 different laboratory experiments and/or investigations of already existing facilities are accomplished to better understand the circumstances of the real environment and to learn more about the type of technology before it is up-scaled from laboratory to pilot scale. Seven of the 15 investigations are already completed and seven are close to be completed (75-90%).

Until M24, five pilot plants or (parts of) treatment trains were operational. Three of them are related to water recovery at the case studies in Nafplio (CS4), Lleida (CS5) and Kalundborg (CS9). One of them is related to material recovery in Lleida (CS5) and the last one is related to energy recovery in Karmiel (CS6).
Until M27, ten additional plants are expected to be operational. Most of them are quite close to be constructed with a progress between 70% and 100% such as the material recovery unit in Rosignano (CS3), final parts of the water recovery treatment train in

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Lleida (CS5), two energy recovery units in Lleida (CS5) and one energy recovery unit in Shafdan (CS6). Even though the progress is only at 25% in Tarragona (CS1), the case study leader expects the two pilot plants for water recovery to be operational until M27 as for the pilot plants in Tain (CS7) dealing with water, nutrient and energy recovery and reuse.
Until M30, the last six pilot plants shall be operational according to the case study leaders. One of the six pilot plants recovers water, one recovers energy and the other four recovery different materials. Especially for those six pilot plants, the contingency plan is to extend and intensify the laboratory and preparatory experiments to gain more important data and experience in depth that suggest to accelerate and to shorten the start-up and optimisation phase of the pilot plants. Even though all case study leaders still expect to complete their pilot test within the project life time of 48 months, time is becoming a critical factor as sufficient time is required to gain experience from the pilots and translate this into best practices for WSIS implementation.
Until all pilot plants will be operational, a very close monitoring of the case studies will be done by the WP1 management team with the case study leaders and the risk officer via regularly meetings. In addition, the presentations referring to D1.2 will be updated every three months until every pilot plant will be operational.

D1.2 is the basis for the demonstration of the ULTIMATE solutions and for the generation of valuable data. Those data will be needed for the technology evidence base (D1.7), for the best practice guidelines (D1.3, D1.4, and D1.5) and also for the assessments of our circular economy solutions (D2.3 and D2.5). Those results will contribute to find suitable strategies for the replication of our concepts and thus, be the basis for the overall exploitation strategy (D5.9).
Hence, the EU-added value of this deliverable is its contribution to crucial deliverables that will foster and boost circular economy solutions in the European industry and the water sector. The collection and open access presentation of the technologies in the technology evidence base (D1.7) will support decision makers and investors to gain a fast overview of the opportunities and proven concepts of circular economy. Together with the Marketplace (D5.5), the technology evidence base can significantly contribute to the transition from a linear to a circular economy in Europe.
ULTIMATE promotes circular economy solutions that are in line with the ambitions of the European Green Deal (European Commission 2019) its Action Plan for Circular Economy (European Commission 2020) to reduce strongly our greenhouse gas emissions, to provide clean water, to maintain healthy soil, make industry resilient and produce cleaner energy. This deliverable (D1.2) presents technologies that can be applied in the frame of the Regulation (EU) 2020/741 on minimum requirements for water reuse, the Regulation (EU) 2019/1009 laying down rules on the making available on the market of EU fertilising products and the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources.

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Abbreviations

AAT	Advanced anaerobic treatment (immobilised high-rate anaerobic reactor)
AnMBR	Anaerobic membrane bioreactor
AnBTMBR	Anaerobic biofilm treatment membrane bioreactor
AOP	Advanced oxidation process
ATES	Aquifer thermal energy storage
BES	Bioelectrochemical systems
CE	Circular economy
COD	Chemical oxygen demand
CS	Case study
CTG	Cross-cutting technology group
ELSAR	Electrostimulated anaerobic reactor
GAC	Granulated activated carbon
HTC	Hydrothermal carbonisation
MBR	Membrane bioreactor
nZLD	Near zero liquid discharge
PE	Population equivalent
RO	Reverse osmosis
SBP	Small bioreactor platform
SCWE	Supercritical water extraction
SME	Small and medium enterprises
TEB	Technology evidence base
UF	Ultrafiltration
WSIS	Water smart industrial symbiosis
WWTP	Wastewater treatment plant

Table of tables

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1. Introduction

In ULTIMATE, water smart industrial symbioses (WSIS) between the industrial sector and service providers of the water sector are established to implement and operate innovative circular economy solutions. The WSIS are considered to be the basis for a successful implementation of those technologies, because one partner produces the resource for the circular economy solution and the other partner has the demand for the recovered product. Thus, they cooperate for their mutual benefits. At nine case studies distributed across Europe and Israel, the ULTIMATE consortium develops and demonstrates 21 pilot plants, which recover water, materials and/or energy (Table 1).

Hereby, eight, six and seven pilot plants refer to water recovery, energy recovery and material recovery and reuse, respectively. The grey coloured technologies refer either to only concept studies or to early warning systems, data-driven matchmaking platforms and/or control systems. Those systems need more time than only 24 months to be investigated and developed. Therefore, they have been excluded from D1.2 that was already indicated in the grant agreement. Their results will be part of the deliverables D1.3, D1.4 and D1.5 *New approaches and best practices for closing the water, material and energy cycles.*

Deliverable D1.2 is a demonstrator type deliverable and is supposed to show, that the ULTIMATE pilot plants are operational. To document that this status has been achieved, for every case study a presentation containing pictures and/or videos of the operational pilot plant will be accessible on the ULTIMATE webpage in the case study section (https://ultimatewater.eu/demonstration-cases/). However, some pilot plants have delays and are not operational yet. For those, the presentations will be updated every three months until all pilot plants are operational. This document accompanies these presentations that are the main evidence for D1.2 and shows the progress until M24.

The baseline conditions of each case study were described in detail in D1.1 (Kleyböcker et al. 2021a) showing the opportunities and the demands for the implementation of the circular economy ULTIMATE concepts. In D1.8 (Kleyböcker et al. 2022), the concepts are explained in detail and discussed in the context of similar research projects and concepts. Hence, D1.2 is the next step towards the overall goal of ULTIMATE to show the successful implementation of the concepts and to derive best practise guidelines for closing the water, material and energy cycles at the case studies within the symbioses clusters. Those results will be presented in detail in D1.6 & D1.7 *Technology Evidence Base* (D1.6, Kleyböcker et al. 2021b) as well as in the deliverables D1.3, D1.4 and D1.5 *New approaches and best practices for closing the water, material and energy cycles*.

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Table 1 Overview about the ULTIMATE solutions: relevant for D1.2 are the blue (water recovery and reuse), green (material recovery and reuse) and yellow (energy recovery and reuse) coloured technologies

Explanation of colour code/scale indication

WATER RECLAMATION AND REUSE	NUTRIENT & MATERIAL RECOVERY & REUSE	ENERGY & HEAT RECOVERY & REUSE
NO PILOT PLANT --> NOT PART OF D1.2	COMBINATION OF THE CS4 PILOT PLANTS FOR WATER & MATERIAL	

CS	Name	Water Smart Industrial Symbiosis – Industrial Sectors: AgroFood	Beverage	Chemical/Petrochemical	BioTech	Service Providers: Municipal utility	Multi-industry utility	Specialist SME providing water services	Technologies applied & Circular Economy contributions		
1	Tarragona (ES)								Zeolite adsorption for ammonia removal from urban reclaimed water, reducing energy consumption of urban WWRP *TRL 5 → 6*	nZLD systems (membranes) for industrial water reuse *TRL 5 → 7*	Concept study for integration of urban and reclaimed water production for industrial water use *TRL 4 → 6*
2	Nieuw Prinsenland (NL)								Water treatment solution for recycling of drainwater from greenhouses allowing safe reuse in horticulture *TRL 4 → 6*	Closed loop greenhouses with water and nutrient recycling *TRL 4 → 6*	HT-ATES for use in greenhouse horticulture to balance out energy supply and demand using industrial residual heat *TRL 5 → 7*
3	Rosignano (IT)								Real-time data driven process control for salinity management to improve reclamation yield from municipal WWTP *TRL 5 → 7*	Data-driven matchmaking platform for water reuse of water from various sources *TRL 5 → 7*	Use of industrial byproducts as wastewater treatment process chemicals in ARETUSA reclamation plant *TRL 4 → 7*
4	Nafplio (EL)								Water reuse in industry after filtration, adsorption, super critical water extraction & AOP *TRL 5 → 7*	Mobile wastewater treatment unit for use in seasonal food processing industry combing both water recovery and material recovery units *TRL 5 → 7*	Extraction of value added compounds from fruit processing wastewater by filtration, adsorption and supercritical fluid extraction *TRL 5 → 7*

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CS	Name	Water Smart Industrial Symbiosis: Industrial Sectors – AgroFood	Industrial Sectors – Beverage	Industrial Sectors – Chemical/Petrochemical	Industrial Sectors – BioTech	Service Providers – Municipal utility	Service Providers – Multi-industry utility	Service Providers – Specialist SME providing water services	Technologies applied & Circular Economy contributions: WATER RECLAMATION AND REUSE	NUTRIENT & MATERIAL RECOVERY & REUSE	ENERGY & HEAT RECOVERY & REUSE
5	Lleida (ES)		■			■	■		Water reuse after treatement with AnMBR and ELSAR with fit-for-purpose post-treatmet: NF & RO: *TRL 7 → 9;* AOP & UV: *TRL 7 → 9;* *Online Monitoring: TRL 5 → 7*	Concept study for nutrient recovery via digestate application in agriculture TRL 5 → 7 Solar-driven hydrothermal carbonisation plant for biochar production *TRL 5 → 6*	Increased yield in biogas production in anaerobic membrane bioreactors AnMBR: *TRL 7 → 9* ELSAR: *TRL 5 → 7* and biogas valorisation: SOFC: *TRL 7 → 9*
6	Karmiel, Shafdan (IL)	■				■		■	Shafdan: Combined immobilised high rate anaerobic filter (AAT) with membrane filtration and activated carbon (AC) for increased biogas production *TRL 5 → 7*	Extraction of value added products from olive mill wastewater by adsorption & supercritical fluid extraction *TRL 5 → 7*	Karmiel: AAT for biogas production from poorly degradable organic matter *TRL 5 → 8*
7	Tain, Scotland (UK)		■					■	RO treatment of AnMBR effluent for water reuse in cleaning processes at the distillery *TRL 5 → 7*	Ammonia recovery from distillery wastewater *TRL 5 → 7* Struvite recovery *TRL 5 → 7*	Heat recovery from AnMBR effluent *TRL 5 → 7*
8	Saint Maurice, l'Exil (FR)			■			■		Flue gas scrubbing & dust removal for sulphur recovery as sodium bisulphite *TRL 4 → 6*	Concept study for a method to recover metals (e.g. Fe, Cu, Zn, Ni, Cr) from flue gas cleaning water *TRL 4 → 6*	Concept study to recover heat from the flue gas washing water for steam or electricity production *TRL 2 → 4*
9	Kalundborg (DK)				■		■		Combination of novel ultrafiltration membranes as pre-treatment for wastewater with high-nondegradable organic matter *TRL 5 → 7*	Concept study for nutrient and/or high-value product recovery (*Integration of solutions of other sites with TRL > 6*)	Data driven control system to increase energy efficiency through a synergetic operation of an industrial and municipal WWTP *TRL 5 → 8*

Explanation of colour code/scale indication: WATER RECLAMATION AND REUSE (blue); NUTRIENT & MATERIAL RECOVERY & REUSE (green); ENERGY & HEAT RECOVERY & REUSE (yellow); NO PILOT PLANT --> NOT PART OF D1.2 (grey); COMBINATION OF THE CS4 PILOT PLANTS FOR WATER & MATERIAL

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The results will also be used for the different assessments and analyses in WP2, they will be used as a basis for potential replication ambitions (WP5), for the identification of policy gabs for the implementation of such technologies (WP4) and the marketability of their products (WP5).

Hence, this deliverable contributes to crucial deliverables that will foster and boost circular economy solutions in the European industry and the water sector. The collection and open access presentation of the technologies in the technology evidence base (D1.7) will support decision makers and investors to gain a fast overview of the opportunities and proven concepts of circular economy. Together with the Marketplace (D5.5), the technology evidence base can significantly contribute to the transition from a linear to a circular economy in Europe.

ULTIMATE promotes circular economy solutions that are in line with the ambitions of the European Green Deal (European Commission 2019) its Action Plan for Circular Economy (European Commission 2020) to reduce strongly our greenhouse gas emissions, to provide clean water, to maintain healthy soil, make industry resilient and produce cleaner energy. This deliverable (D1.2) presents technologies that can be applied in the frame of the Regulation (EU) 2020/741 on minimum requirements for water reuse, the Regulation (EU) 2019/1009 laying down rules on the making available on the market of EU fertilising products and the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources.

2. Operational demo cases

In ULTIMATE, 21 pilot plants are developed and will be demonstrated at nine case studies to showcase innovative circular economy solutions (Table 2). Furthermore, CS1 - CS8 conduct laboratory experiments, before they implement their pilot plants. In total, 15 different laboratory experiments and/or investigations of already existing facilities are accomplished to better understand the circumstances of the real environment and to learn more about the type of technology before it is up-scaled from laboratory to pilot scale.

Table 2 Overview about the resources and pilot plants referring to each case study

Case study	Resources	Treatment trains
CS1 Tarragona (ES)	Municipal wastewater and industrial wastewater from the petrochemical complex	**Water recovery**: reverse osmosis and membrane distillation **Water recovery**: ammonia removal via zeolites
CS2 Nieuw Prinsenland (NL)	Drain water from greenhouses; residual and geothermal heat	**Water recovery**: reclamation of greenhouse drain water using electrodialysis **Material recovery**: recovery of nutrients including test beddings and demo greenhouse
CS3 Rosignano (IT)	Byproducts from industry for reuse in water treatment	**Material recovery and reuse**: pilot scale adsorption system & use of byproducts
CS4 Nafplio (EL)	Wastewater from fruit processing industry	**Water recovery**: filtration, advanced oxidation and small bioreactor platform **Material recovery**: plant to recover antioxidants
CS5 Lleida (ES)	Wastewater from brewery & municipal wastewater	**Water recovery**: nanofiltration & reverse osmosis as part of the post-treatment **Material recovery**: solar-driven hydrothermal carbonisation demo plant **Water recovery**: Advanced oxidation & UV light treatment **Energy recovery**: Anaerobic membrane bioreactor **Energy recovery**: Solid oxide fuel cell **Energy recovery**: Full-scale electrostimulated anaerobic reactor (ELSAR)
CS6 Karmiel/ Shafdan (IL)	Wastewater from olive oil production, slaughterhouses and wineries & municipal wastewater	**Energy recovery**: Biogas production from olive mill wastewater: high rate anaerobic reactor **Energy recovery**: High rate anaerobic reactor with membrane filtration incl. PAC **Material recovery**: plant to recover polyphenols

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Case study	Resources	Treatment trains
CS7 Tain (UK)	Wastewater from whiskey distillery	**Water recovery**: reverse osmosis to treat AnMBR effluent **Energy recovery**: heat recovery unit **Material recovery**: struvite and ammonia sulphate recovery units
CS8 Chem. Platform Roussillion (FR)	Wastewater from chemical industry	**Material recovery**: sulphur recovery unit
CS9 Kalundborg (DK)	Wastewater from pharma & biotech industry and municipal wastewater	**Water recovery**: Treatment train for water recovery involving a novel ultrafiltration membrane

In the following chapters, the progress per case study referring to the relevant subtasks for D1.2 are shown in detail.

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2.1. CS1: Tarragona

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
1	1.2.1	RO + MD; ammonia removal via zeolites	100%	25%		25

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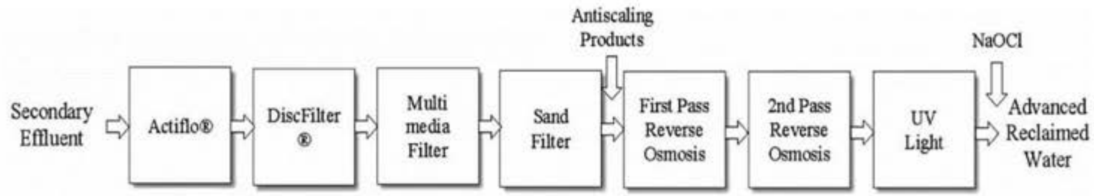
CS1: Situation before Ultimate

✓ The Tarragona and Vilaseca-Salou wastewater treatment plants (WWTPs) were interconnected by a 4-km pipeline to ensure that the AWRP can be supplied with enough secondary effluent from either or both WWTPs. Secondary effluent undergoes a basic **water reclamation process** at **the WRP** (1021 m^3/h average inlet flow rate), consisting of a ballasted clarification step (Actiflo® unit), followed by disc filtration (DiscFilter® unit), multimedia filtration and sand filtration. The effluent undergoes an advanced reclamation process including a two-pass reverse osmosis (RO) treatment processes and disinfection, using ultra-violet light and chlorine, before it enters the reclaimed water distribution system.
Furthermore, chemical reagents such as coagulant, flocculent and antiscaling are added to enhance the plant performance.



✓ On the other hand, in order to meet future water requirements (BREF limits), an **industrial wastewater treatment plant (iWWTP)** has been commissioned in April 2022 to polish the aggregated wastewater from the petrochemical complex and to produce reclaimed water for the complex (1348 m^3/h average water flow rate). The technology train to be implemented in these new facilities will be:

- Dissolved air flotation (DAF)
- Biological membranes (MBR)
- Granular activated carbon (GAC)

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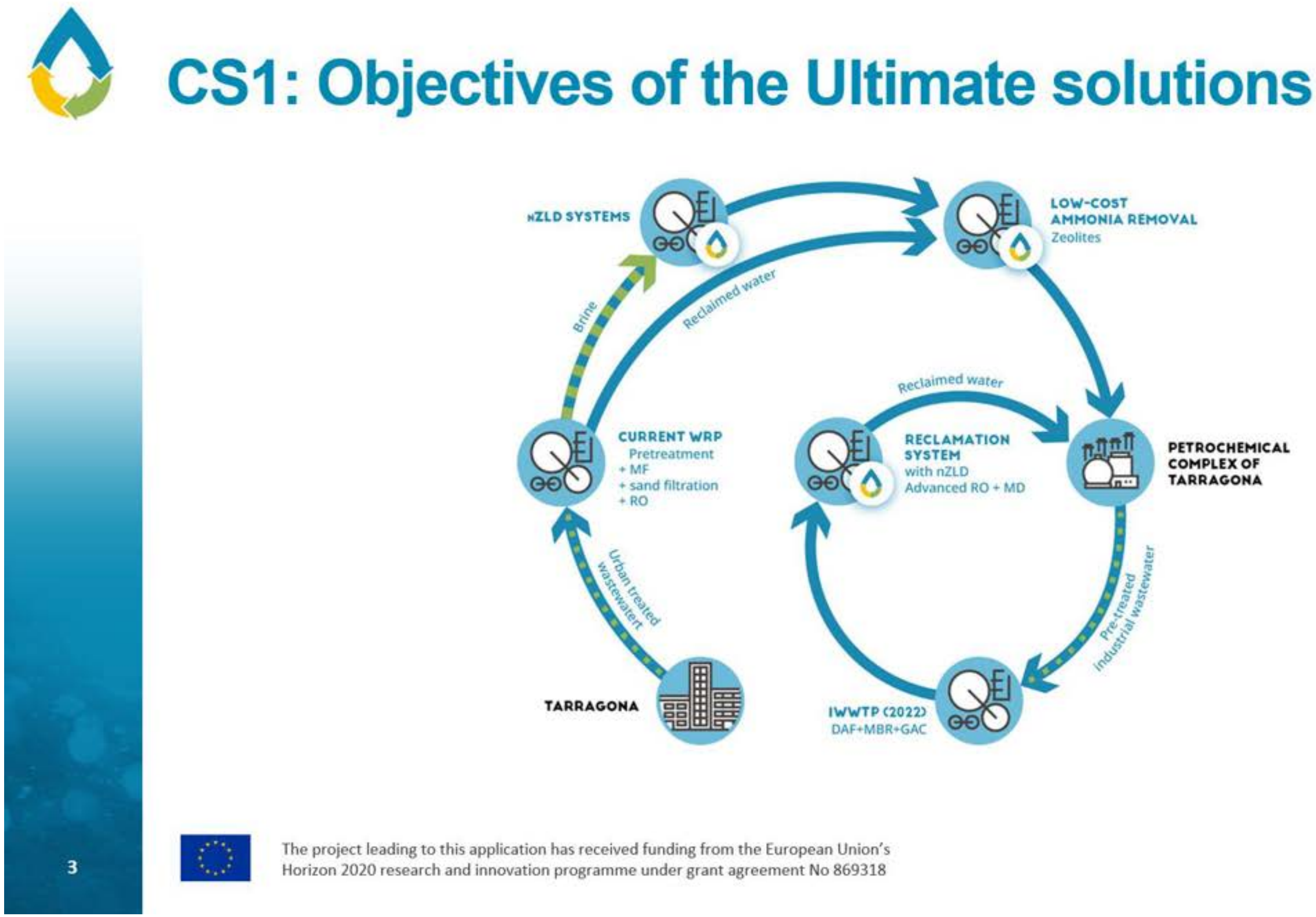

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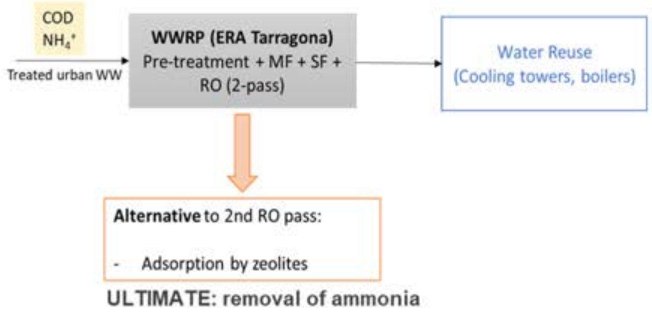
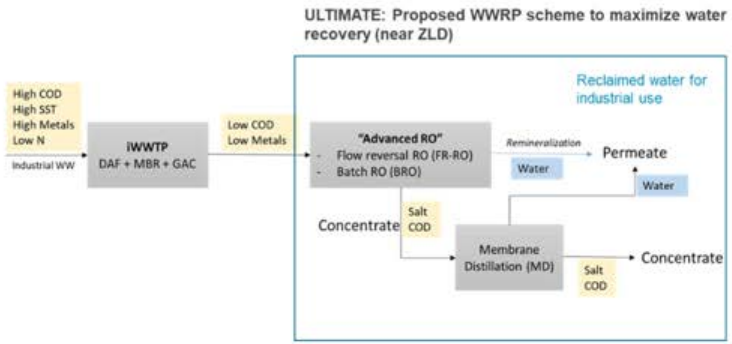
CS1: Objectives of the Ultimate solutions

OBJECTIVE:
Increase reclaimed water availability for the complex by 20%:

→ **Current WWRP**:
- → Increase water recovery of the current WWRP with nZLD technologies
- → Remove the ammonium with low-cost technology (zeolite adsorption)



→ **Future iWWTP**:
- → Defining a novel tertiary treatment with nZLD technologies (reverse osmosis and membrane distillation) to obtain reclaimed water



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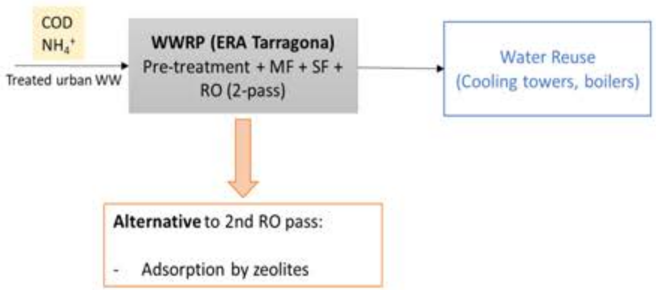
CS1: Status/progress

Subtask: 1.2.1 Increasing reclaimed water availability of the petrochemical complex of Tarragona (ES)

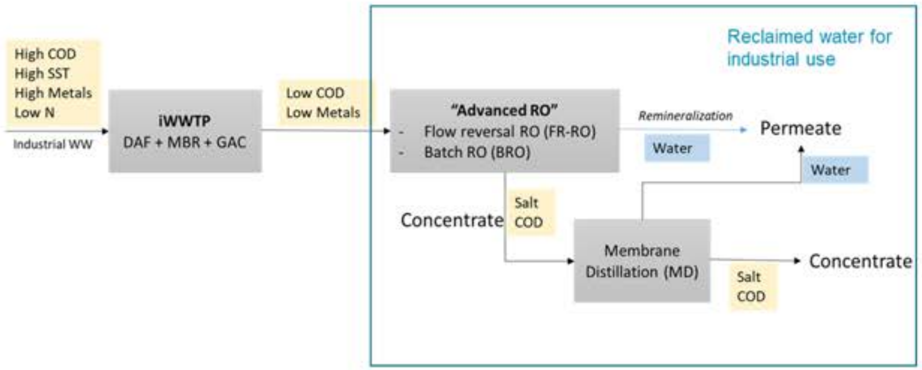
Baseline technology: WWRP (pre-treatment+MF+SF+2-pass RO), iWWTP in operation in April 2022.

Ultimate solution to foster circular economy:



ULTIMATE: removal of ammonia

ULTIMATE: Proposed WWRP scheme to maximize water recovery (near ZLD)



TRL: 5→7 (membranes), 5→6 (adsorption on zeolites)

Capacity: 12 m³/d

Quantifiable target: <20% reduction of fresh water through reuse of treated wastewater; 10 % reduction of energy demand

Status/progress:

- Bench scale experiments finished (UF, RO, MD and adsorption on zeolites)
- Pilot plant ordered (two different suppliers)
- Adsorption process designed by Eurecat/AITASA

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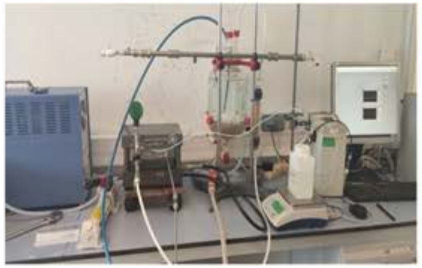
CS1: Pictures/videos of the new technologies

Subtask: 1.2.1 Increasing reclaimed water availability of the petrochemical complex of Tarragona (ES)

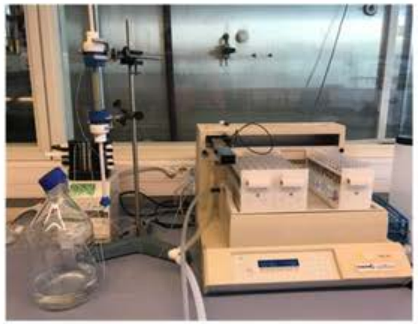
Optimal operation conditions obtained experimentally at bench scale→ Pilot plant design

UF bench scale experimental set-up



RO bench scale experimental set-up

MD bench scale experimental set-up



Zeolite adsorption bench scale experimental set-up

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CS1: Operational procedures and methodologies

Subtask: 1.2.1 Increasing reclaimed water availability of the petrochemical complex of Tarragona (ES)

- Work at bench scale is finished.
- Pilot plant:
  - UF+ batch RO pilot plant ordered to supplier 1
  - MD pilot plant ordered to supplier 2
  - Adsorption pilot plant designed by Eurecat/AITASA
  - AITASA is preparing the pilot plant location (pilot plant will be inside a 40 ft maritim container)

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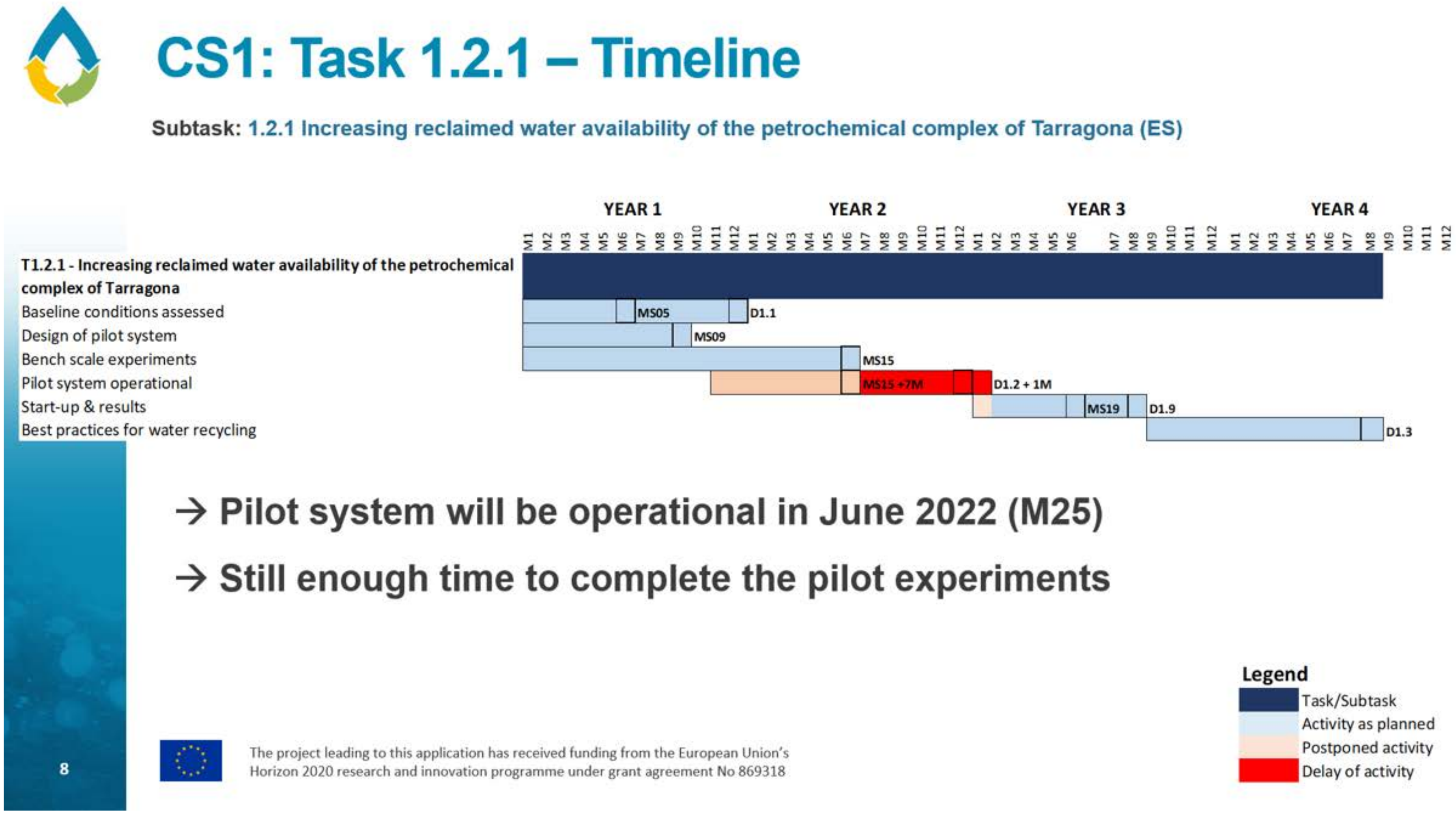

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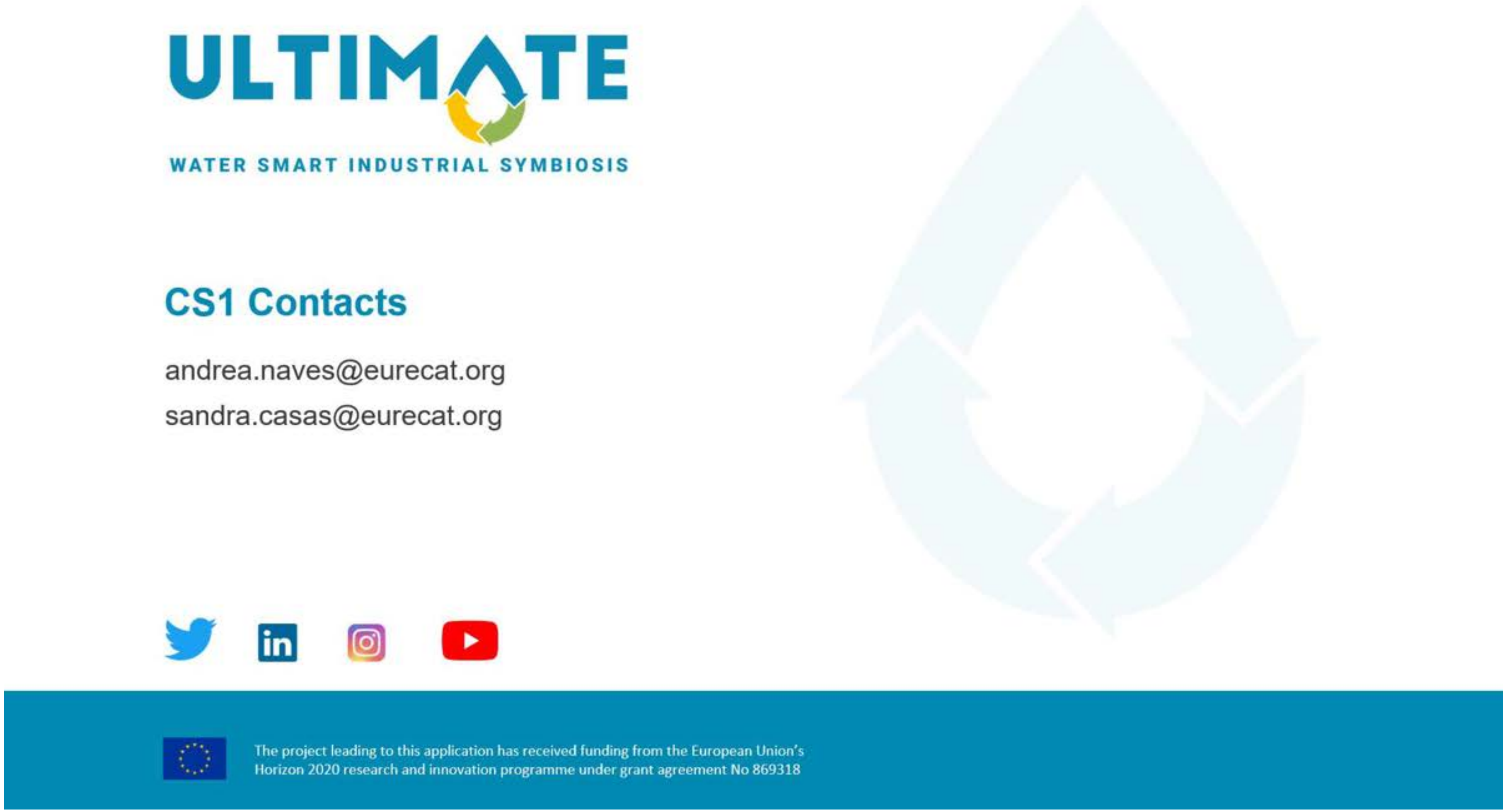

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2.2. CS2: Nieuw Prinsenland

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
2	1.2.2	Reclamation of greenhouse drain water using electrodialysis	75%	25%		28
	1.3.1	HT-ATES	No pilot plant --> excluded from D1.2			
	1.4.1	Recovery of nutrients: test beddings & demo greenhouse	75%	25%		28

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CS2: Situation before Ultimate

Situation at the Coöperatieve Tuinbouw Water Zuivering de Vlot (November 2020)

The current status is that the wastewater treatment plant is operational. From January 2021, they can remove crop protection agents from the wastewater. The cooperative aims to start working towards reusing/recovering water and nutrients from 2021 onwards.

Process steps at the site:

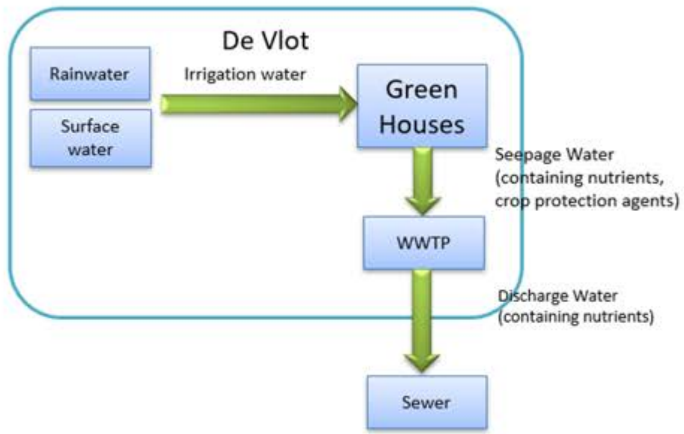
Prefiltration by vibrating and rotating filters: suspended solids removal

Coagulation in sedimentation buffers: P removal

Sand filtration with glycerol dosage: N removal (not operational as high nutrient load results in clogging and hence too high maintenance)

Activated carbon: crop protection agent removal

Current hydrological cycle De Vlot



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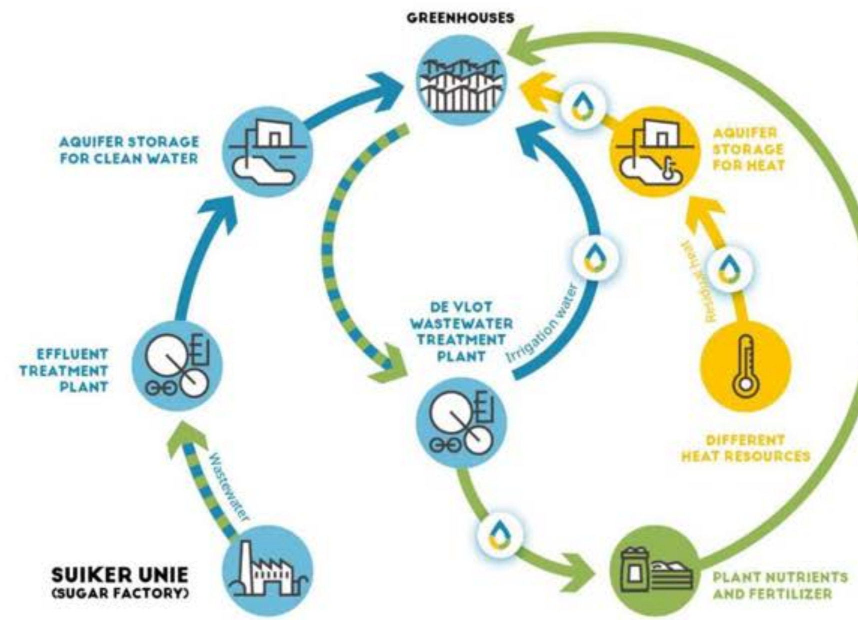
CS2: Objectives of the Ultimate solutions



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CS2: Objectives of the Ultimate solutions

WATER: Task 1.2.2 (KWR) Optimizing water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

The main aim of this task is to facilitate the reuse of wastewater from greenhouses with a view on optimizing the water reclamation. To do so, an extensive analysis of the treated wastewater will be conducted. Then, an adequate treatment will be determined supported by a quantitative microbial risk assessment (WP2), so that water suitable for irrigation purposes (main objectives - free of pathogens, low in sodium) can be supplied for irrigation in the greenhouses.

In order to validate a reliable way of removing plant diseases from the water, the reuse of this water will be investigated on pilot scale in a demo-greenhouse.

Finally, a full-scale treatment solution will be designed based on the previous results and the ones of the economic analysis (WP2).

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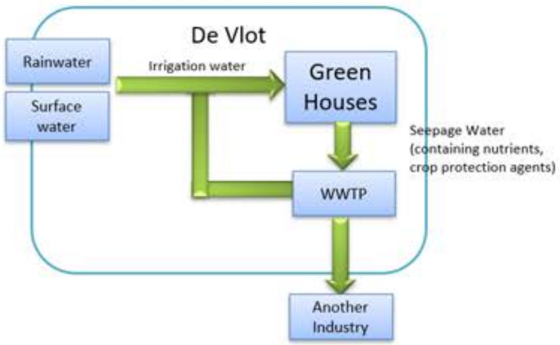
CS2: Subtask 1.2.2 Status/progress

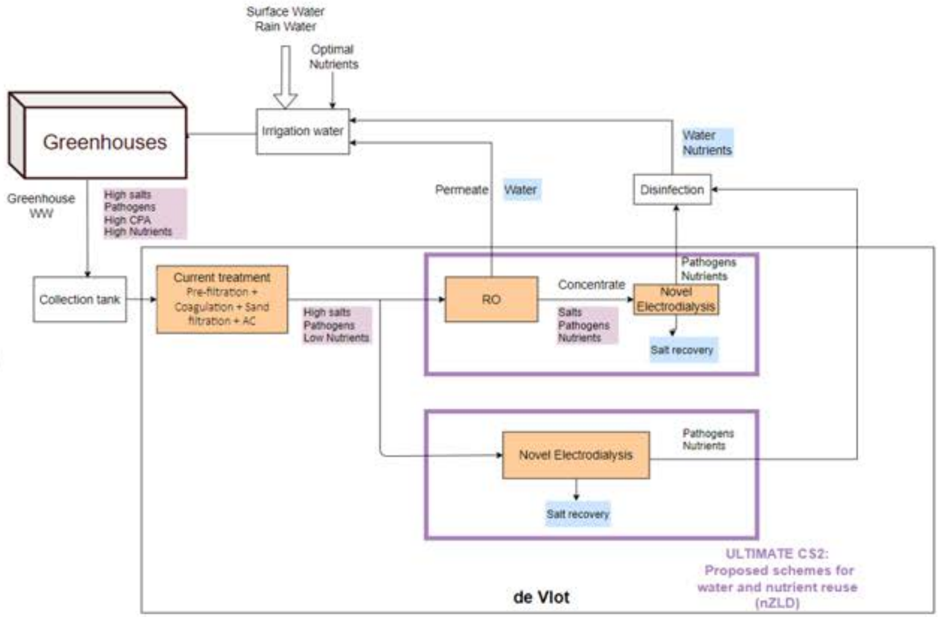
Subtask: 1.2.2 Optimising water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

Baseline technology: no water reuse so far

Ultimate solution to foster circular economy:

New hydrological cycle





TRL: 4 → 6

Capacity of the pilot plant: 0.1 m³/day

Quantifiable target: ambition beyond the project: 25% reduction of freshwater through water reuse (700 m³/d)

Status/progress:

- Performance validation for Proof of Concept on laboratory scale being finalized.
- Detailed pilot design – completed
- Construction of pilot plant – acquisition of components ongoing, construction started first half of May 2022

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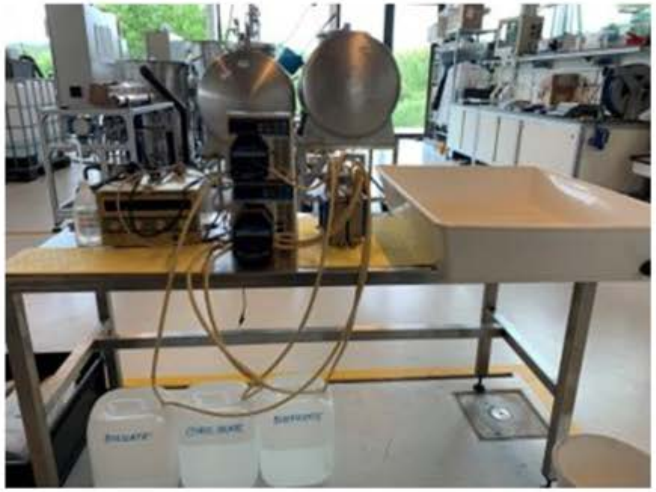
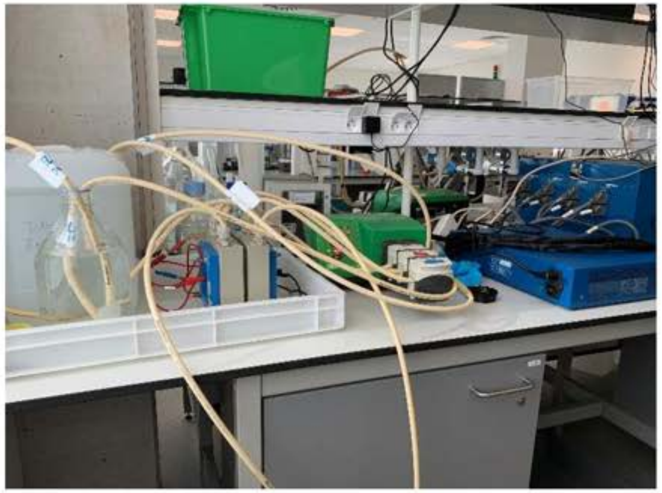
CS2: Pictures/videos of the new technologies

Subtask: 1.2.2 Optimising water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

Electrodialysis experiments



Lab experiments ongoing at KWR



Lab experiments ongoing at Ghent University

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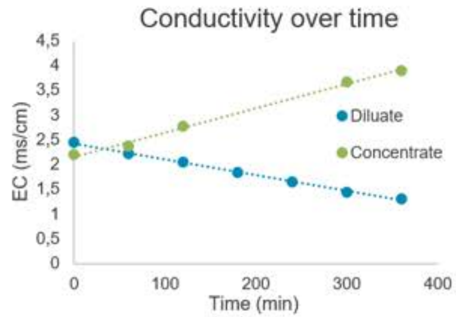
CS2: Results of the laboratory experiments

Subtask: 1.2.2 Optimising water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

- Results of initial experiments with NaCl simulated wastewater
- NaCl removal performance for salts with high and low concentrations with similar operation conditions
- 60% reduction in EC (1 ms/cm) (~50% Na removal)
- On-going optimization lab experiments with Greenhouse simulated wastewater



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CS2: Operational procedures and methodologies

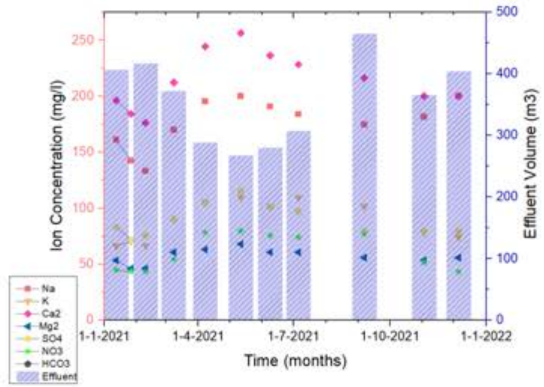
Subtask: 1.2.2 Optimising water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

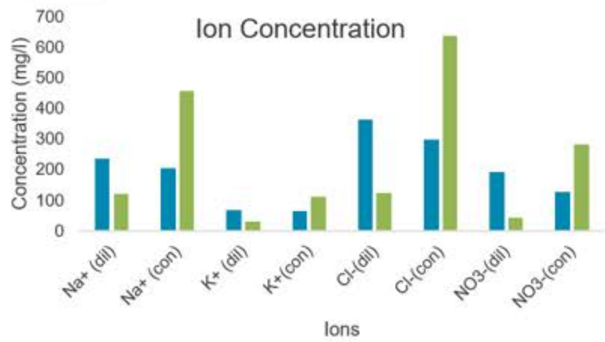
Work to date has focused on validation of the methodology on lab scale and confirming the required performance in selective removal of sodium can be achieved.

- Experiments conducted for simulated greenhouse wastewater for ion removal performance

Design of the pilot has been completed based on the outcomes of the bench scale tests.

Operational procedures will be developed by operating the pilot plant on KWR premises before it is moved to the field location.





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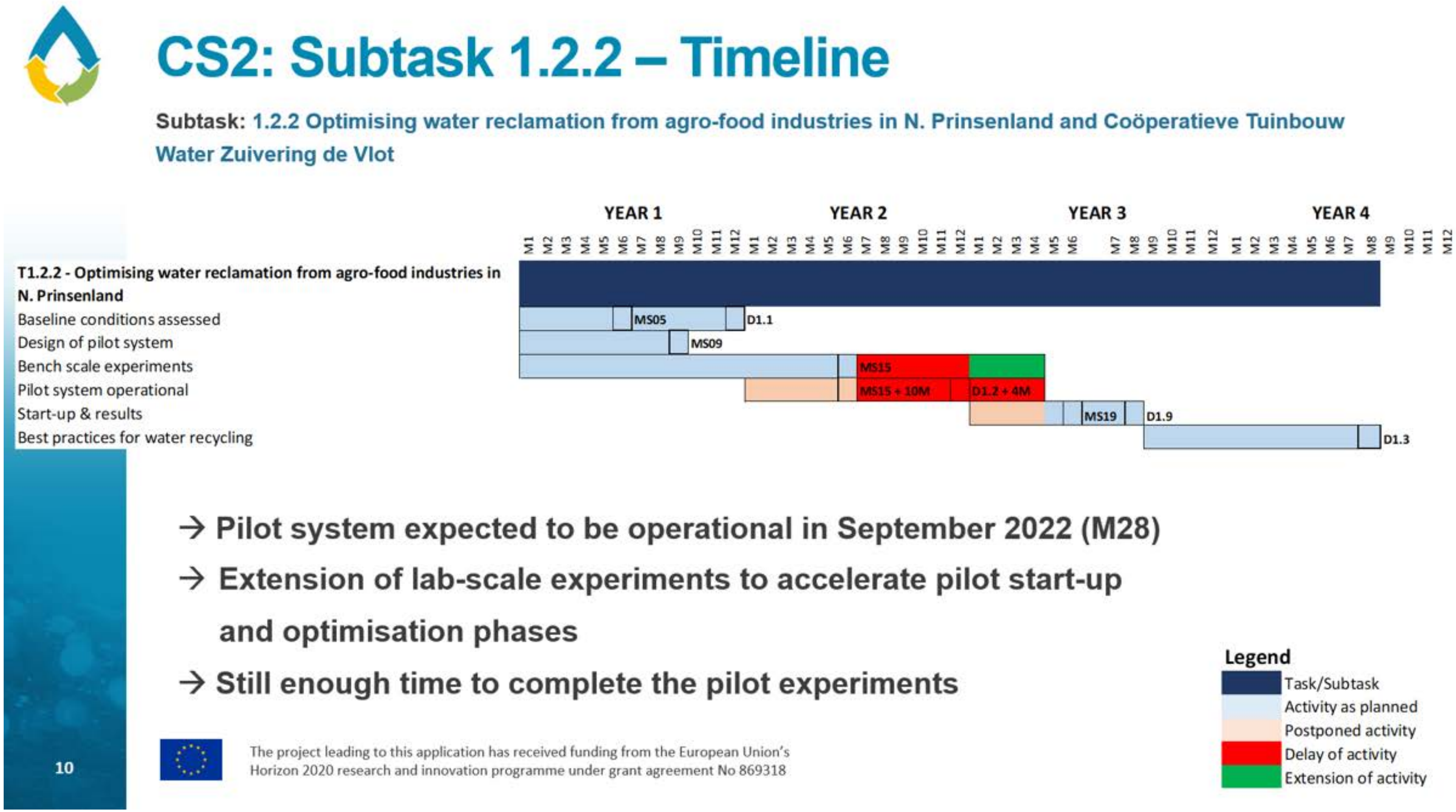

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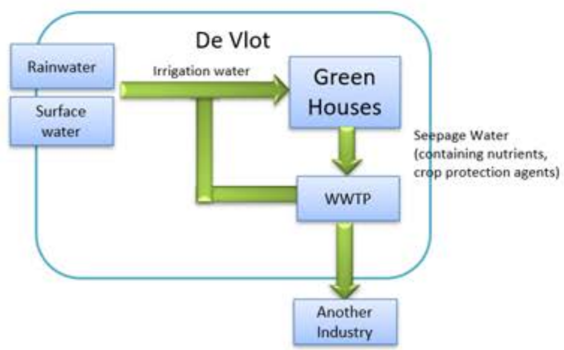
CS2: Subtask 1.4.1 Status/progress

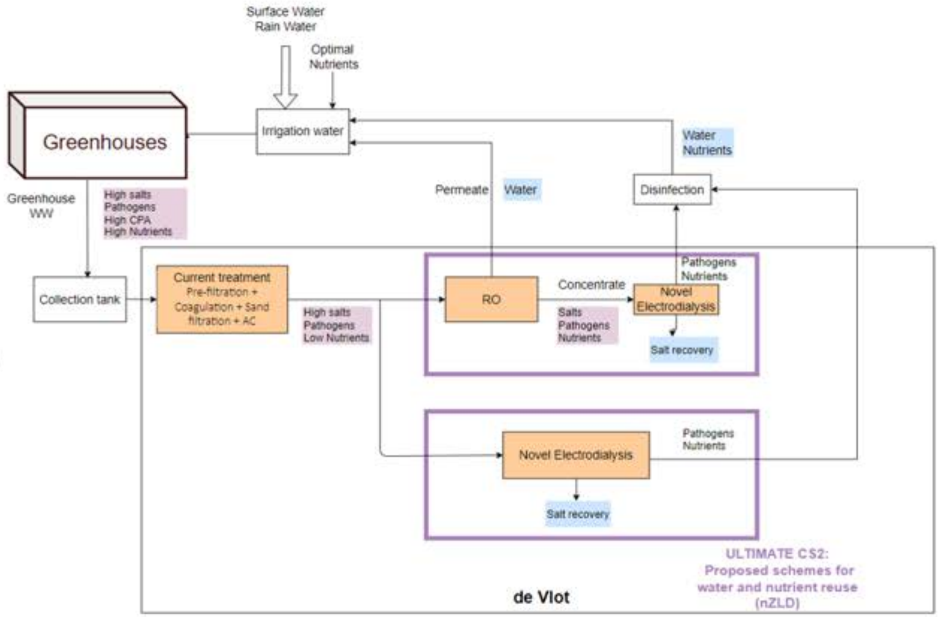
Subtask: 1.4.1 Recovery of nutrients from greenhouse wastewater in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

Baseline technology:

Ultimate solution to foster circular economy:

New hydrological cycle





TRL: 4 → 6

Capacity: 0.1 m³/day (K recovery & N recovery)

Quantifiable target: first results 55% K recovery; 75% N recovery; 60% Ca recovery; 55% Mg recovery

Status/progress:

- **Performance validation for Proof of Concept on laboratory scale being finalized.**
- **Detailed pilot design – completed**
- **Construction of pilot plant – acquisition of components ongoing, construction starts first half of May 2022**

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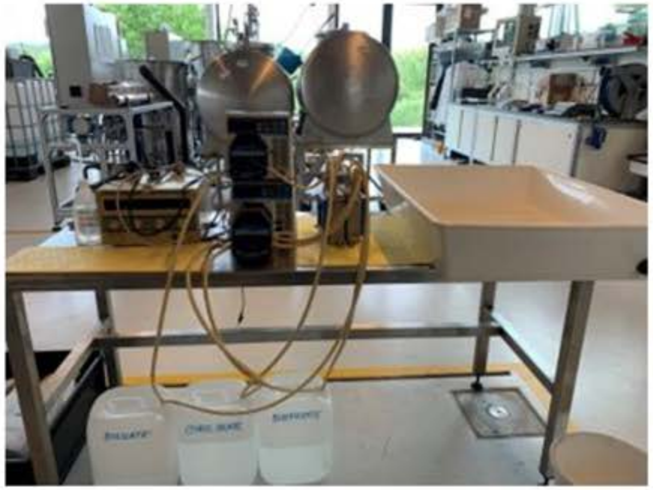
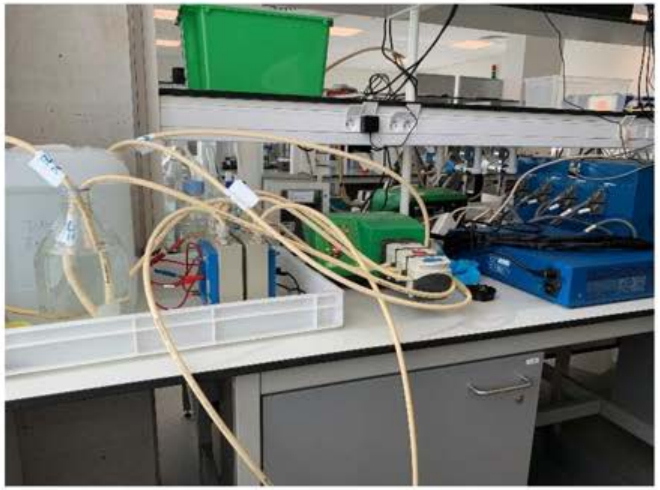
CS2: Pictures/videos of the new technologies

Subtask: 1.4.1 Recovery of nutrients from greenhouse wastewater in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

Electrodialysis experiments



Lab experiments ongoing at KWR



Lab experiments ongoing at Ghent University

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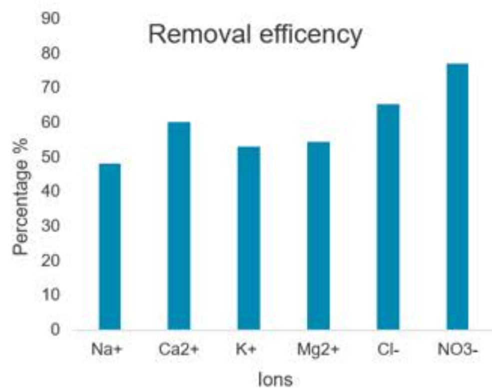
CS2: Results of the laboratory experiments

Subtask: **1.4.1 Recovery of nutrients from greenhouse wastewater in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot**

See also subtask 1.2.2: For the recovery of nutrients and their reuse, the removal of sodium is required. Thus, the described experiments in subtask 1.2.2 do also apply to this subtask 1.4.1.



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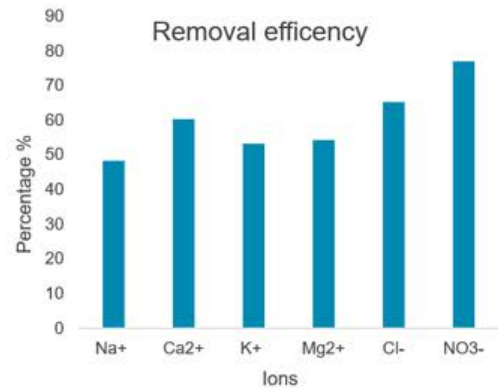
CS2: Operational procedures and methodologies

Subtask: 1.4.1 Recovery of nutrients from greenhouse wastewater in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

For the recovery of nutrients, the following treatment steps are being established:

1) Removal of sodium
2) Efficiency in retaining nutrients (N, P, K) in the matrix
3) Optimal operational conditions and energy requirements



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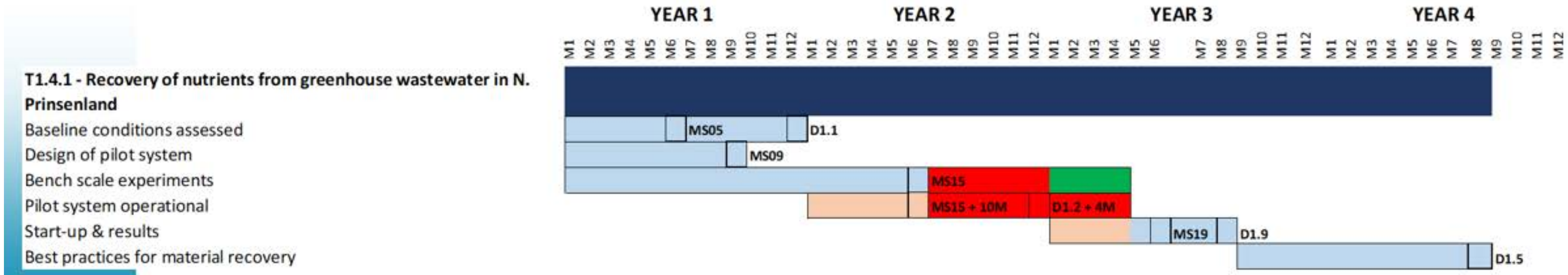
CS2: Subtask 1.4.1 – Timeline

Subtask: 1.4.1 Recovery of nutrients from greenhouse wastewater in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot



→ Pilot system expected to be operational in September 2022 (M28)

→ Extension of lab-scale experiments to accelerate pilot start-up and optimisation phases

→ Still enough time to complete the pilot experiments

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ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS2 Contacts

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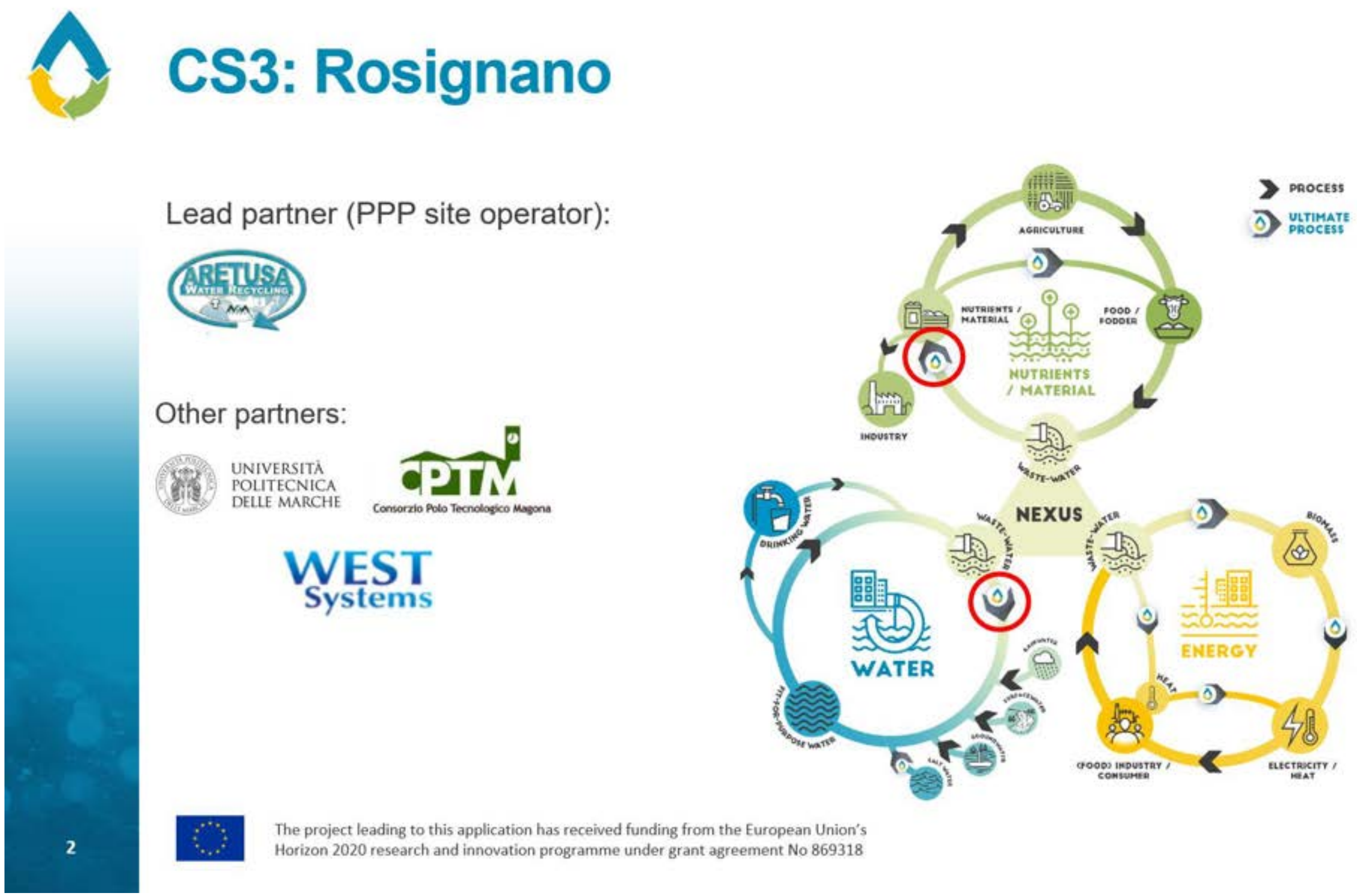
2.3. CS3: Rosignano

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
3	1.2.3	Control system to aviod high chlorine concentrations	No pilot plant --> excluded from D1.2			
	1.4.2	Use of byproducts: pilot scale adsorption system	85%	80%		25



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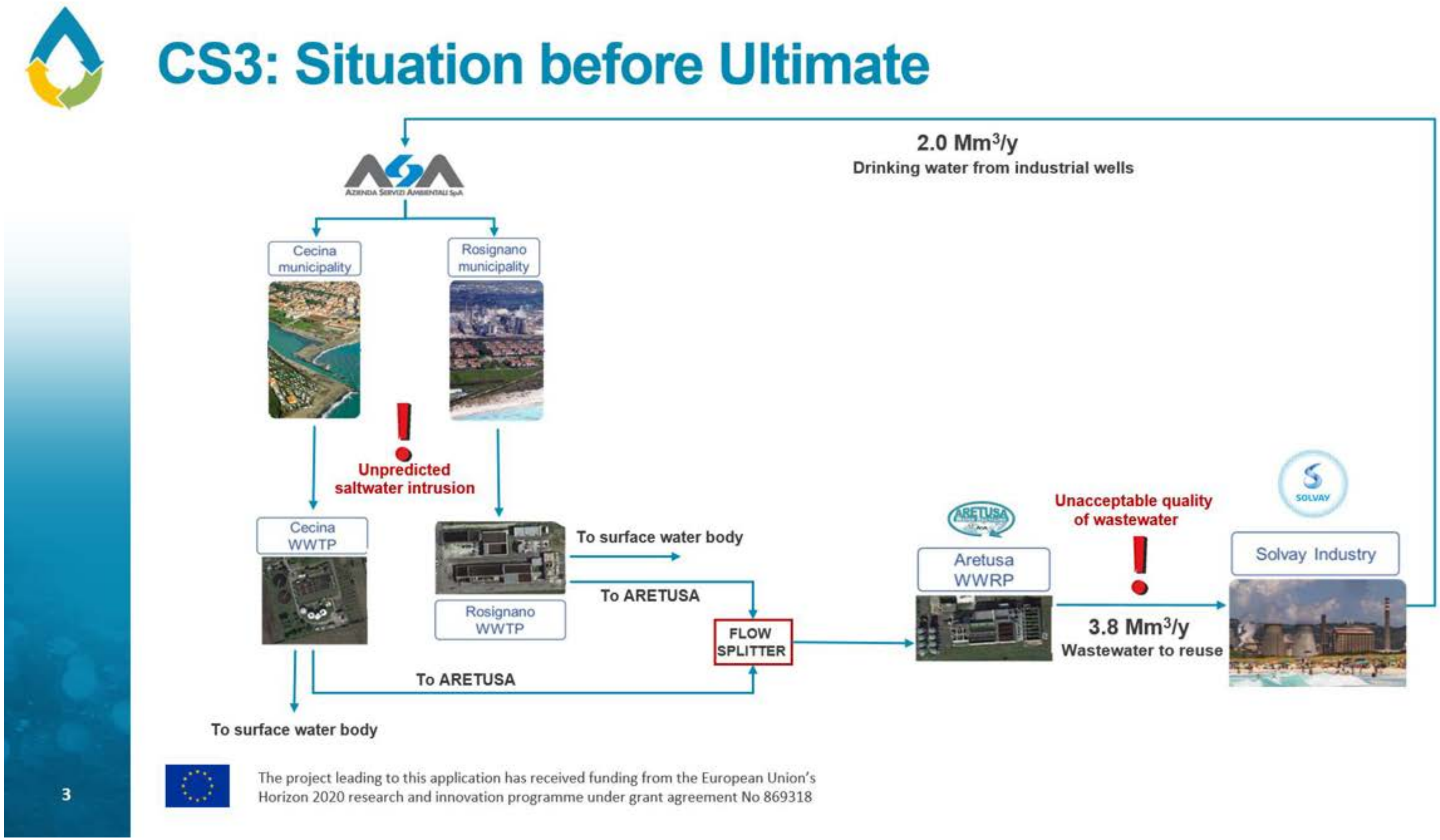

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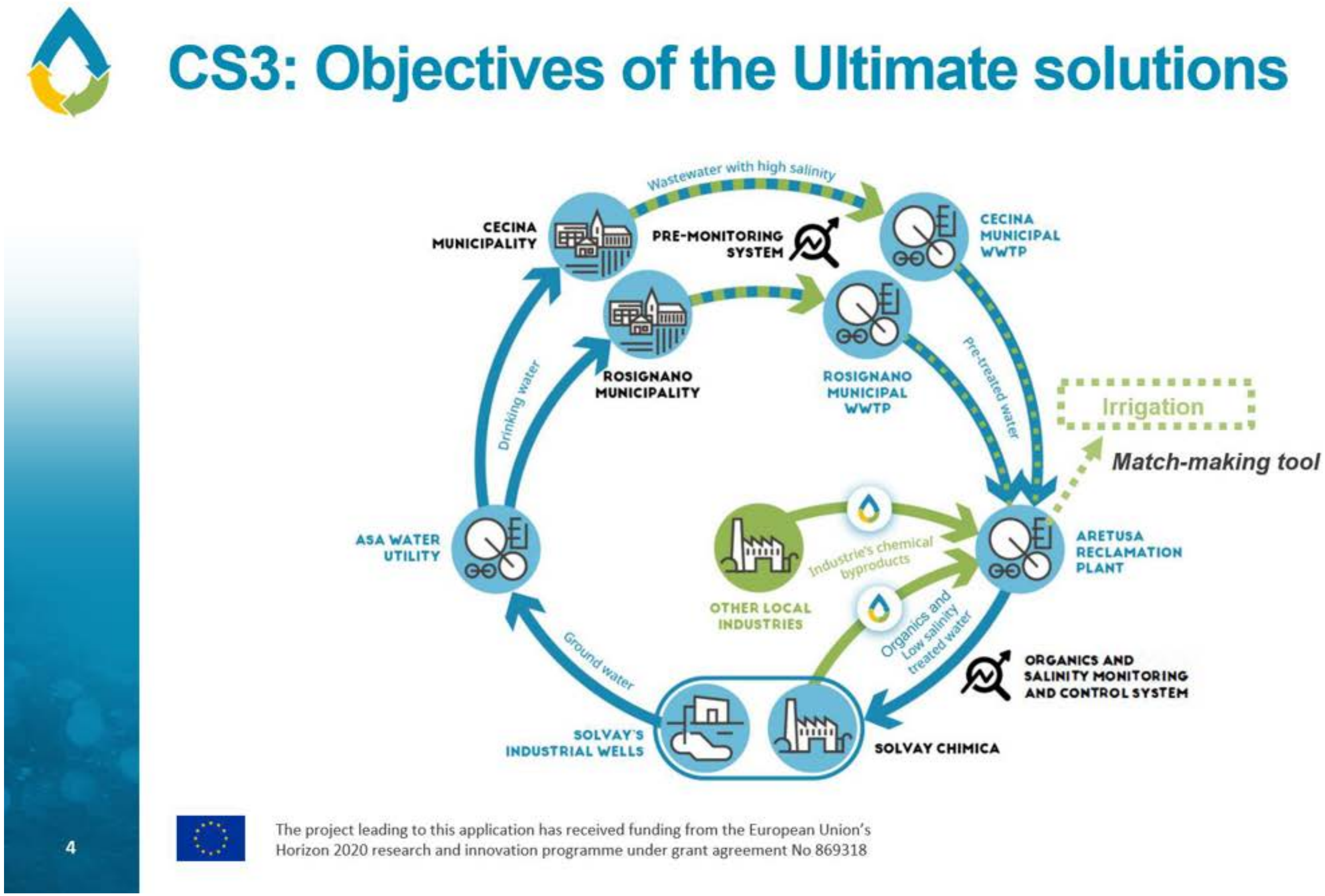

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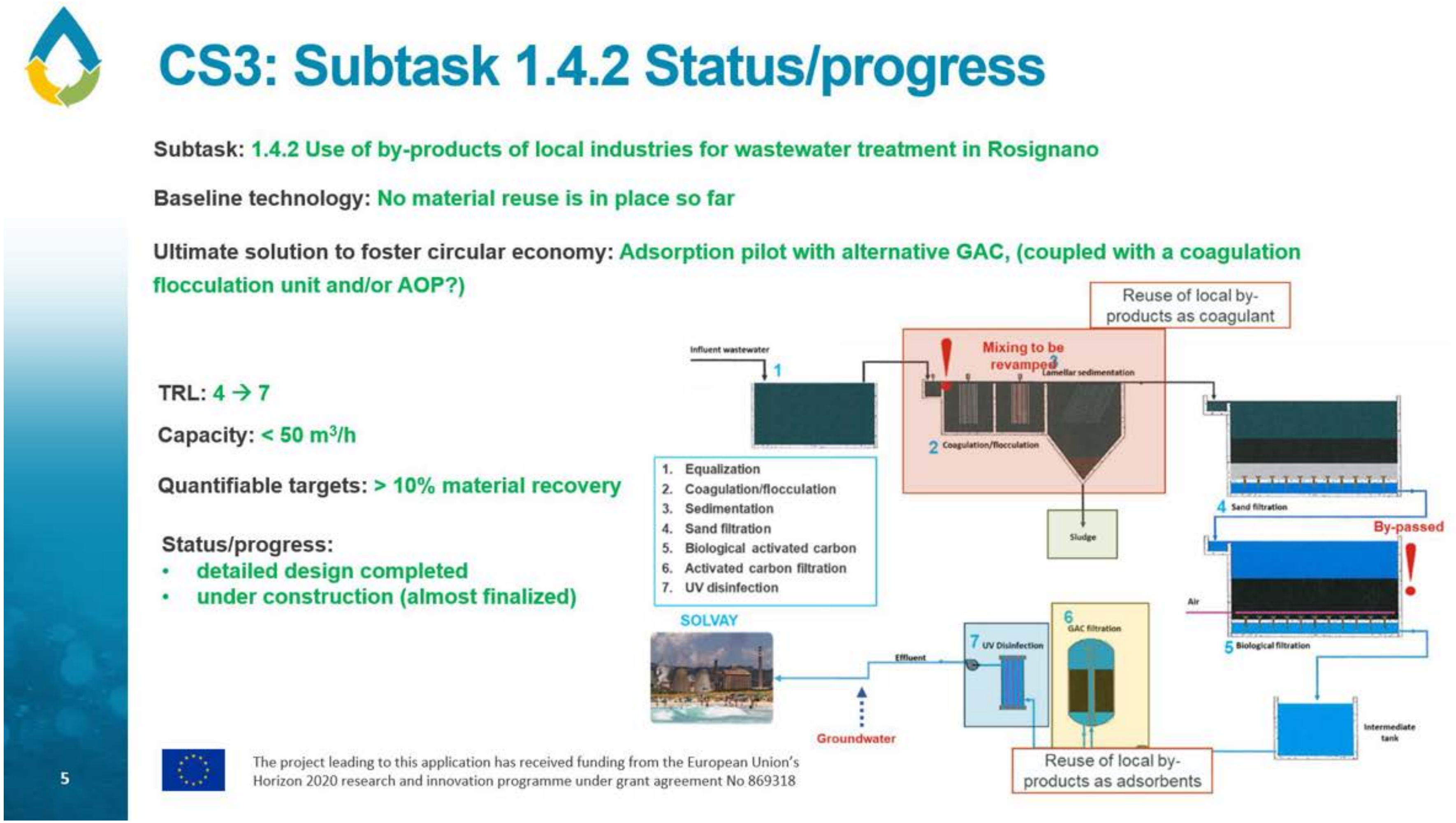

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CS3: Results of the functional test

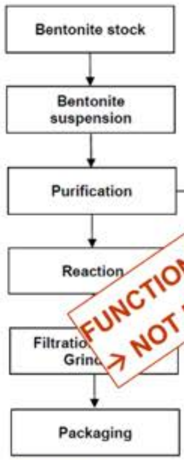
Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

MATERIALS (BY-PRODUCTS) CARACTERIZATION

ORGANOCLAY (LAV1)

LAVIOSA Advanced Mineral Solutions

Laviosa Chimica Mineraria SpA extracts, process and distributes industrial mineral products, in particular bentonitic products and special 'modified' b... ...ic products called "Organo-clay". From the necessary purification stages in the org... ...oduction process comes this **'grit' that is poor in bentonite but rich in zeolit... ...ates**.



FUNCTIONAL TESTS SHOWED LOW PERFORMANCES → NOT FURTHER TEST OR SCALE-UP

...one ai raggi X dimostrano che la fase più abbondante risulta quella ...o silicate quali calcite, plagioclasio, miche ed altri riportati nella tabella

...RD

Fase	Quantità [%]
Zeoliti	33
Calcite	28
Plagioclasio	15
Quarzo	10
Mica	8
K-feldspato	6

L'umidità risulta mediamente del 35 % in massa e la perdita alla calcinazione del 11,67 %.

La composizione degli ossidi invece risulta come nella seguente tabella:

Oxides composition

Analita	Quantità [%]
Na_2O	1,80
MgO	0,86
Al_2O_3	11,75
SiO_2	59,05
P_2O_5	0,35
K_2O	2,76
CaO	9,85
TiO_2	0,30
MnO	0,40
Fe_2O_3	1,22

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COMMERCIAL ACTIVATED CARBON (CA)

TES

CARBONE ATTIVO GRANULARE **FA 300-SB**

Origine	Antracite attivata con vapore d'acqua	
Granulometria, U.S. Mesh.	8 x 30 > 8 (2,36 mm) < 30 (0,60 mm)	ASTM D 2862 5 % max. 4 % max.
Densità apparente, g/l	490 - 540	ASTM D 2854
Umidità all'imballaggio, %	< 2	ASTM D 2867
Durezza, %	> 95	ASTM D 3802
Indice di abrasione, %	> 90	AWWA B 604/74
Indice di Iodio, mg/g	> 950	ASTM D 4607
Indice di Blu di Metilene, mg /g	> 220	Spettrofotometrico

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CS3: Results of the functional test

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

MATERIALS (BY-PRODUCTS) CARACTERIZATION: HYDROCHAR ACTIVATION

Physical activation – ATT1

- Heating of the char pellets in a tubular oven up to 700°C (5°C/min) with N2 purging.
- CO2 flushing and isotherm for 2 hr.
- Cooling of the tubular furnace in N2 purging.

47% WEIGHT LOSS

Chemical activation – ATT4

- Impregnation of char pellets in KOH aq. solution (KOH to char ratio: 1:1) at 60°C for 6 hr.
- Drying of the impregnated char at 105°C.
- Heating in a tubular oven up to 600°C (5°C/min), isotherm at 600°C for 1 hr and cooling (5°C/min) with N2 purging.
- Washing with 1M HCl and demi water (up to pH 7).
- Drying at 105°C until constant weight.

55% WEIGHT LOSS

Chemical activation – ATT5-ATT6/7

- Mixing of the char pellets (previously grounded) with KOH in flakes (KOH to char ratio: 1:1).
- Heating in a tubular oven up to 600°C (5°C/min), isotherm at 600°C for 1 hr and cooling (5°C/min) with N2 purging.
- Washing with 5M HCl and demi water (up to pH 7).
- Drying at 105°C until constant weight.

60% WEIGHT LOSS

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CS3: Results of the functional test

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

MATERIALS (BY-PRODUCTS) CARACTERIZATION

	LAV1	HC	HC ATT1	HC ATT4	HC ATT5
F^-	< 0.1	54.2	0.2	0.4	< 0,1
Cl^-	2,5	44.4	62.5	26.4	1.7
$NO3^-$	0.2	1.3	< 0,1	< 0,1	< 0,1
$PO4^{---}$	3.2	38.5	< 0,1	54.3	8.4
$SO4^{--}$	32.9	147.3	143.9	110.2	103.4
COD	81	4200	< 15	< 15	< 15

- ✓ *RAW (NOT ACTIVATED) HYDROCHAR CONTAINS TAR → HIGH COD*
- ✓ *NEED OF PRE-TREATMENT (WASHING) OF RAW HYDROCHAR (NOT ACTIVATED)*

	LAV1	HC ATT1	HC ATT4	HC ATT5	CA1
Specific surface area (m^2/g)	6	117	449	752	1100÷1150
Specific pore volume (cm^3/g)	0.003	0.055	0.214	0.359	-
Average pore radius(Å)	50.23	13.61	15.16	16.08	-

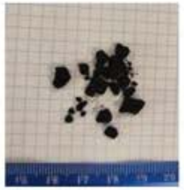
- ✓ *COMMERCIAL ACTIVATED CARBON (CA) WAS USED AS REFERENCE FOR THE ADSORPTION TESTS*
- ✓ *HIGH SURPHACE AREA DEVELOPED BY ACTIVATED HYDROCHAR*

LAV 1
Organo Clay

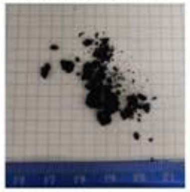
HC
Hydrochar

HC ATT 1
Activated HC

HC ATT 4
Activated HC



HC ATT 5-6-7
Activated HC



CA1
Activated carbon

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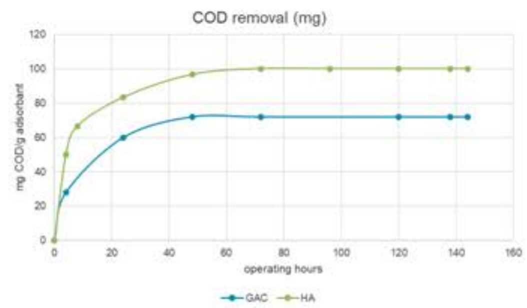
CS3: Results of the functional test

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

ADSORPTION TESTS

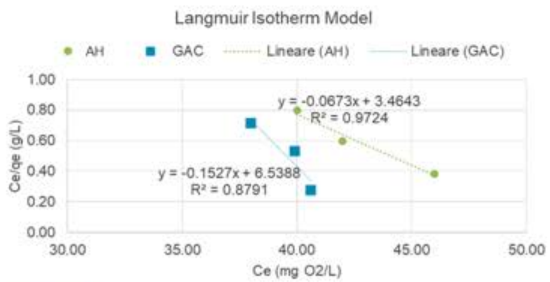
Material tested: Activated Hydrochar (AH) and Commercial Granular Activated Carbon (GAC)

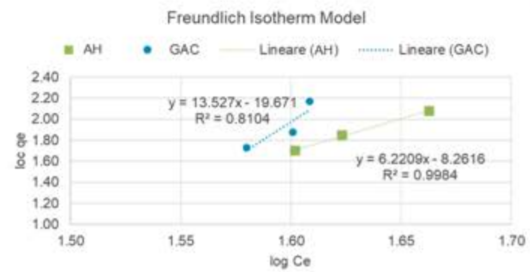
KINETIC AND ISOTHERM WITH MUNICIPAL WASTEWATER



KINETIC	EQUATION	PARAMETERS		GAC	HTC
Pseudo-First Order	$\log(qe - qt) = \log(qe) - \frac{k_1 t}{2.303}$	k1	min^{-1}	0.164	0.148
		R^2		0.987	0.968
Pseudo-Second Order	$\frac{t}{qt} = \frac{1}{k_2 qe^2} \frac{t}{qe}$	k2	g/mg/min	0.003	0.002
		R^2		0.999	0.999

ISOTHERM	EQUATION	PARAMETERS		GAC	HTC
Freundlich	$\log qe = \log Kf + (1/n) \log Ce$	1/n	-	13.53	6.221
		Kf	$(mg/g)(L/mg)^{1/n}$	2.86E-09	2.58E-4
		R^2	-	0.810	0.998
Langmuir	$\frac{Ce}{qe} = \frac{1}{ab} + \frac{1}{a} Ce$	a	mg/g	6.547	14.87
		b	L/mg	0.023	0.019
		R^2	-	0.879	0.972





- ✓ *AH has a higher % of COD removal in a shorter time: in the first 8 hours 60% of COD was removed with HA and 25% with GAC.*
- ✓ *Both AH and GAC have better fit with a kinetic of Pseudo Second Order while for Isotherm model Langmuir is to be preferred to Freundlich model.*
- ✓ *100 mg and 70 mg of COD was removed by AH and GAC respectively, after 72 operating hours.*

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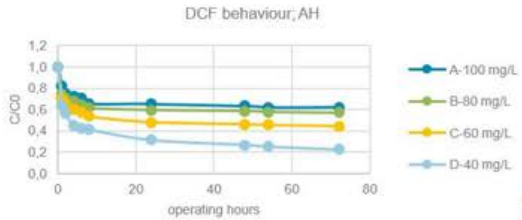
CS3: Results of the functional test

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

ADSORPTION TESTS

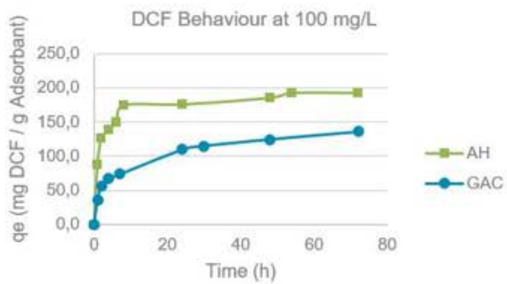
Material tested: Activated Hydrochar (AH) and Commercial Granular Activated Carbon (GAC)

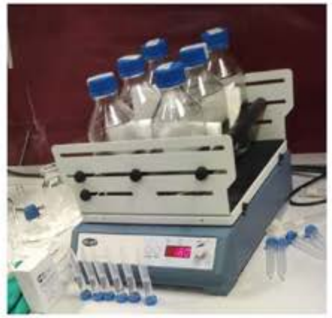
KINETIC WITH DICLOFENAC SOLUTION



ADSORBANT MATERIAL: GAC							
KINETICS	EQUATION	PARAMETERS		A	B	C	D
Pseudo-first Order	$\log(qe-qt)=\log(qe)-\frac{k_1 t}{2.303}$	k1	min^{-1}	0.06	0.07	0.07	0.07
		R^2	-	0.93	0.96	0.97	0.97
Pseduo-Second Order	$\frac{t}{qt}=\frac{1}{k_2 qe^2}\frac{t}{qe}$	k2	g/mg/min	0.001	0.001	0.001	0.001
		R^2	-	0.999	0.999	0.999	0.999

ADSORBANT MATERIAL: AH							
EQUATION		PARAMETERS		A	B	C	D
Pseudo-First Order	$\log(qe-qt)=\log qe-\frac{k_1 t}{2.303}$	k1	min^{-1}	0.20	0.148	0.129	0.116
		R^2	-	0.803	0.863	0.893	0.899
Pseudo-Second Order	$\frac{t}{qt}=\frac{1}{k_2 qe^2}\frac{t}{qe}$	k2	g/mg/min	0.003	0.005	0.003	0.003
		R^2	-	0.999	0.999	0.999	0.999





Experimental Setup for Batch Tests

- ✓ *The adsorption capacity of DCF was 191.9 and 151.4 mg DCF/g for AH and GAC, respectively.*
- ✓ *The adsorption equilibrium is reached, after 72 operating hours for HTC and after 144 hours for GAC*

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CS3: Results of the functional test

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

MATERIALS (BY-PRODUCTS) CARACTERIZATION

- ✓ "Precotto": granulated limestone rocks only partially calcinated and slacked, with a declared content of Ca(OH)2 of about 9%.

- ✓ Na_2CO_3 "Soda Solvay® Light" product that resulted to be out of specification.

Solvay Chimica Italia SpA by-products tested

SOFTENING/COAGULATION/FLOCCULATION TESTS

SUBSTRATE	SOFT. AGENT	COAGULANT	FLOCCULANT	Final pH	COD Removal (%)	Mg Removal (%)	Ca Removal (%)
Influent municipal wastewater	Commercial SODA 1M			8.5-10		0	< 53
Influent municipal wastewater	Soda Solvay			8.5-10		0	44-80
Influent municipal wastewater	Precotto			8.5-10		4-8	< 35
Influent municipal wastewater		Alluminium Sulphate	Poly		64	2.6	4.1
Influent municipal wastewater	Precotto		Poly	8-9.5	49-58	0	17-24
Effluent wastewater		Alluminium Sulphate	Poly		39	9.2	11.4
Effluent wastewater	Precotto		Poly	8-9.5	25-40	7-19	0
Effluent wastewater	Soda Solvay		Poly	8-9.5	< 10	0	7-45

- ✓ *Solvay by-products proved to be successful in reducing COD and, even if with lower performances, also Magnesium and Calcium*
- ✓ *Final test are now being performed to optimize the dosage*

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CS3: Pictures/videos of the new technologies

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

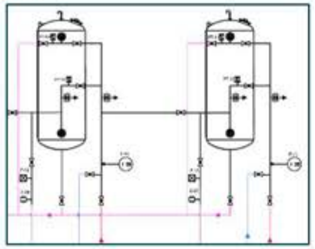
CONSTRUCTION FINALIZED

Adsorption column

Tank for meters (POT)

TO BE IMPLEMENTED
(in order -> to be delivered)

- ✓ *Addition of 2 smaller columns (total number of column will still be 4)*
- ✓ *Equipment of the system with sensors:*
  - Conductivity
  - pH
  - UV/Vis (COD, BOD5 and TOC)
  - Fluorescence
- ✓ *Electrical cabinet*



ID	INSTRUMENTS	Q. ty	Position	Characteristics
PT-01:08	Pressure transmitter	8	Influent and effluent from each column	0 – 4 bar (Sensitivity 0.01 bar)
S-01	pH meter	1	Effluent	pH:0-14; T=-5° C - 50° C
S-02	UV/Vis meter (254 nm)	1	Effluent	Measuring cell: 5 mm Measuring range: 0.1-600.0 m-1 Calibrable on the COD and TOC parameters Compensation: 550 nm Cleaning system: automatic by wiper Measuring interval:> 1 min
S-03	Fluorimeter	1	Effluent	filter band for wavelengths centered on ex/em 345/440 nm
S-04	Conductivity meter	1	Effluent	250 µS - 2,5 S/cm
F-01	Electromagnetic water meter	1	Effluent	0.5– 10 m3/h

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CS3: Pictures/videos of the new technologies

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

PILOT SYSTEM UNDER CONSTRUCTION

The project leading to this application has receive
Horizon 2020 research and innovation programm

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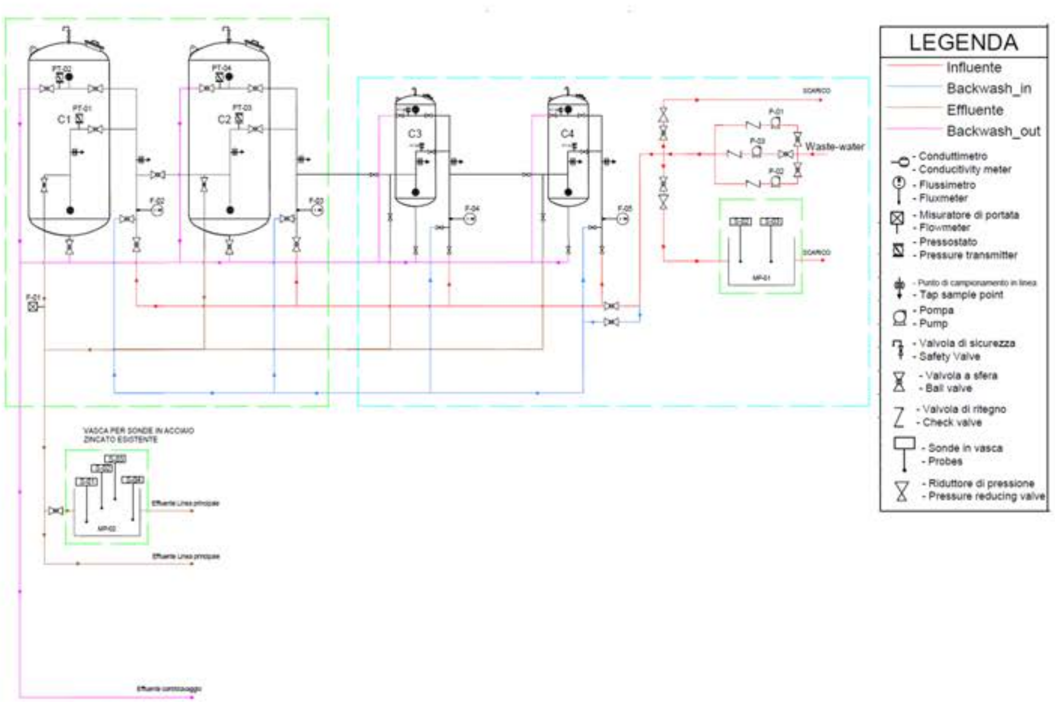
CS3: Operational procedures and methodologies

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano



- ✓ Pilot plant has been designed to allow the **use of columns both in series and in parallel**
- ✓ The pilot is able to **work with different flow rates** in order to optimize the operation of bigger and smaller columns.
- ✓ **Pressure** in all the columns will be **monitored online** to check when it is necessary to proceed with **back-washing operations that will be carried out with a counter-current water flow.**
- ✓ **Conductivity, pH and COD** (UV/Vis and fluorescence) **will be monitored** at the exit of the pilot. COD will be monitored also in the incoming flow.
- ✓ **All sensors, pressure transmitters and pumps will be connected to the electrical cabinet and data will be available online**
- ✓ The pilot will be firstly installed and operated at the pilot hall of UNIVPM and than will be transported and installed at ARETUSA site

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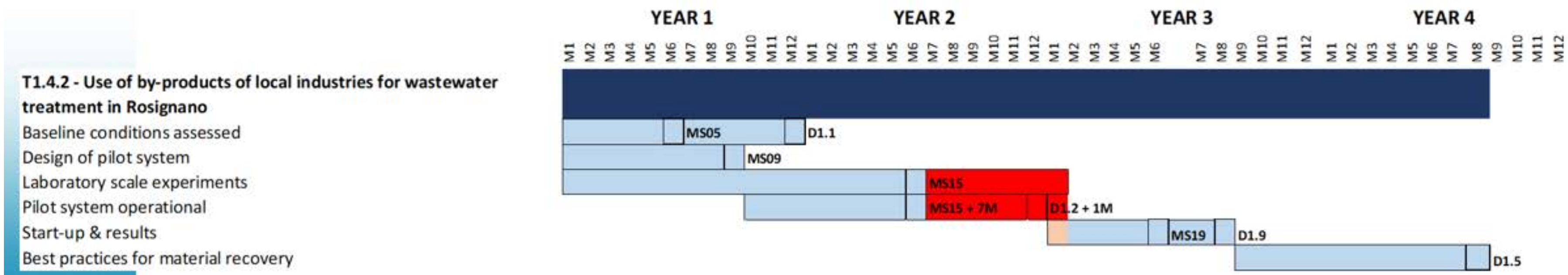
CS3: Subtask 1.4.2 – Timeline

Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano



→ **Pilot system expected to be operational in June 2022 (M25)**

→ **Still enough time to complete the pilot experiments**

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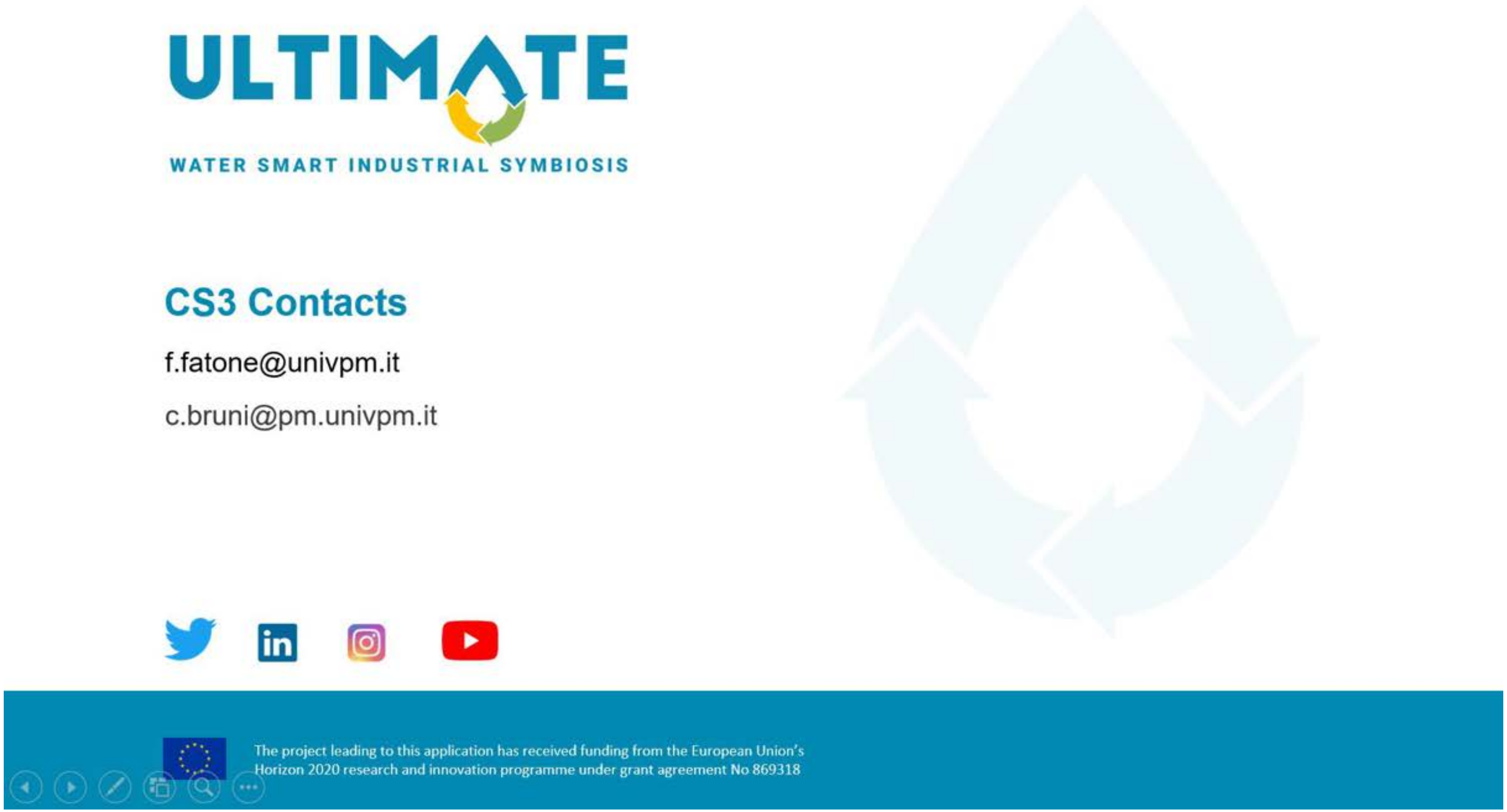

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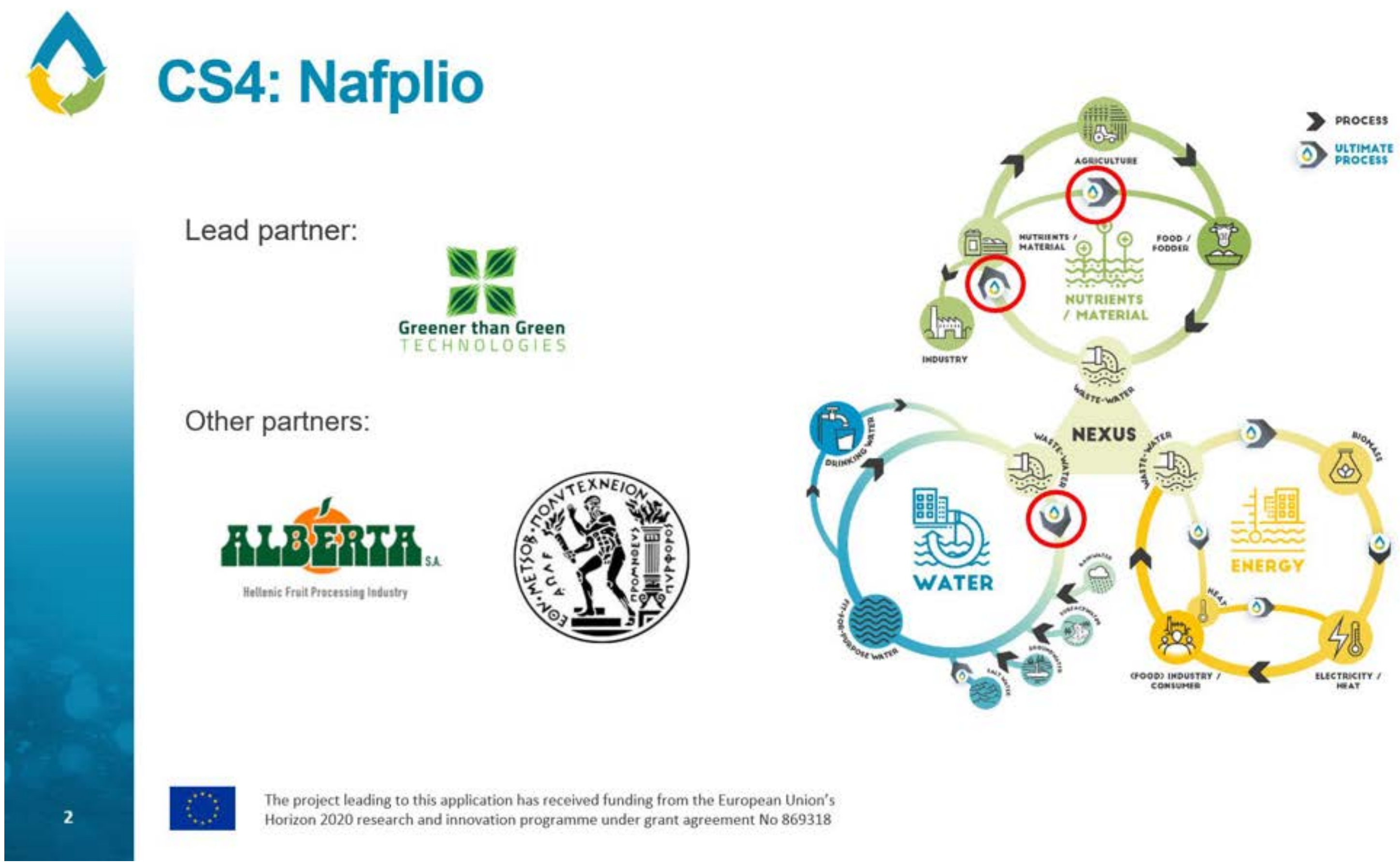
2.4. CS4: Nafplio

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
4	1.2.4	Reuse of fruit processing WW: filtration, AOP, SBP	100%	100%	100%	24
	1.4.3	Recovery of antioxidants: adsorption/extraction	100%	85%		30



CS4: Situation before Ultimate

Argolida area:
- increasing water demand for irrigation
- high-water consumption of the fruit processing industry

→ great pressure on regional aquifer

Alberta S.A has a primary treatment unit of about 20 m^3/h capacity:
- high production periods (Nov.-Mar. & Aug.-Oct.): 3500 m^3 WW/d
- other months: 500 m^3 WW/d
- treatment unit consists of a series of tank:

Raw wastewater tank → Rotostrainer →Less solids tank → equalization/ homogeneous tank → Neutralization tank → Pre Sedimentation tank → Aeration tank → Flocculation tank → Final sedimentation tank → Final tank of treated water → Central treatment unit of local water authority (DEYARM)

Aim of the Ultimate solutions (after the implementation of the additional pilot wastewater treatment process):

→to achieve lower organic burden in the final effluent,

→compliant to limits specified by the local water management authority

  →either for disposal to the local final treatment unit,

  →either for irrigation

  →or for reuse in the production procedure of Alberta S.A.

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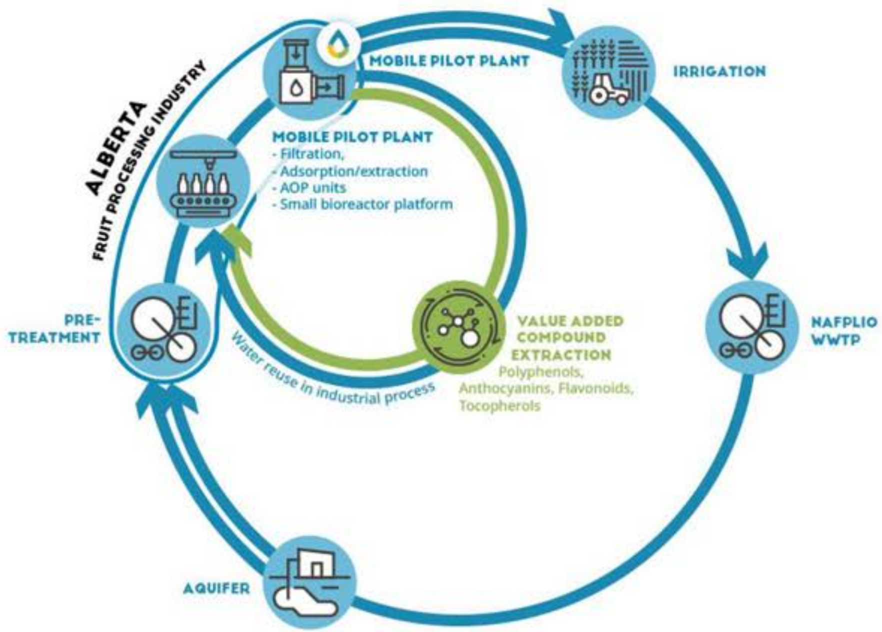
CS4: Objectives of the Ultimate solutions



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CS4: Objectives of the Ultimate solutions

Ultimate aims to address the various issues involved in fresh-water management and reduce wastewater disposal cost. Thus, different techniques are to be implemented to guarantee a sustainable management of the end-of-the-pipe wastewater effluents derived from the food industry, and also to prevent the losses of inorganic and organic pollutants to the environment, making it easier to recycle/reuse the purified water.

The activities in ULTIMATE target both the recovery of various inorganic and organic contaminants from the processing water and the reuse of the purified water. In Alberta's fruit processing plant, a mobile pilot plant will demonstrate a hybrid adsorption / SubCritical Water Extraction (SCWE) process to extract high value-added compounds, such as antioxidants from the wastewater. Residual wastewater will be treated in pilot-scale by an AOP before polishing in an on-site Small Bioreactor Platform (SBP) for reuse in irrigation or discharge into the municipal WWTP to reduce operational costs. The extracted compounds will be assessed for their use by Alberta making "fortified juice" with antioxidant properties, increasing the value of their product, but also by selling the extract to the food-supplement sector.

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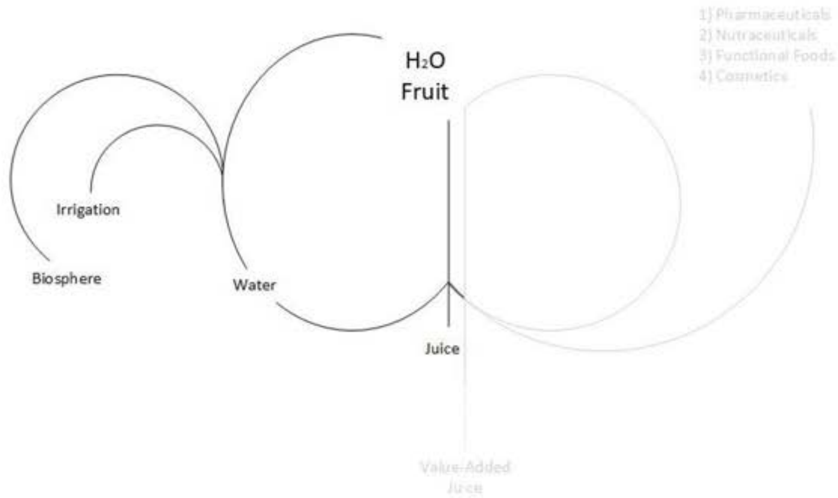
CS4: Subtask 1.2.4 Status/progress

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio
Baseline technology: no water reuse so far

Ultimate solution to foster circular economy:



TRL: 5→7

Capacity: 10 m³/d

Quantifiable target: Ambition beyond the project: 100% water reuse for irrigation; >90% reduction of freshwater through water reuse

Status/progress:

- detailed design completed
- The unit has been installed in Nafplio / several parts to be integrated

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CS4: Pictures/videos of the new technologies

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

The unit installed in Nafplio

AOP

AOP operating with Alberta's wastewater

CS4 video

SBP capsules

Coagulation tests

Sensors

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CS4: Pictures/videos of the new technologies

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

The unit installed in Nafplio

Dossing pumps

TOC analyzer

Sensors

Unit installation video

SBP capsules

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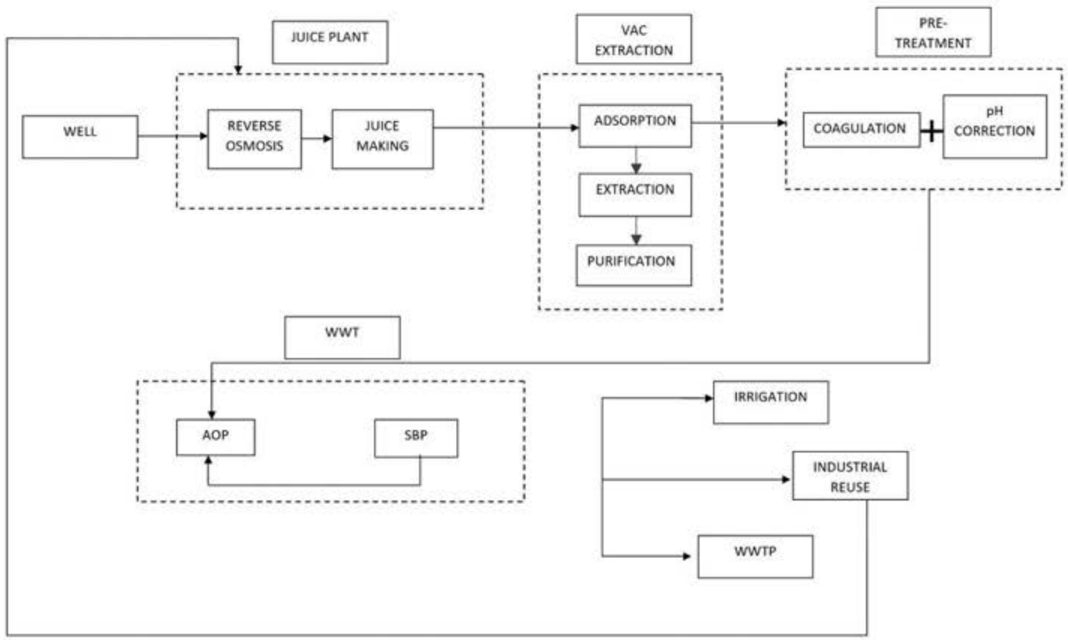
CS4: Operational procedures and methodologies

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio



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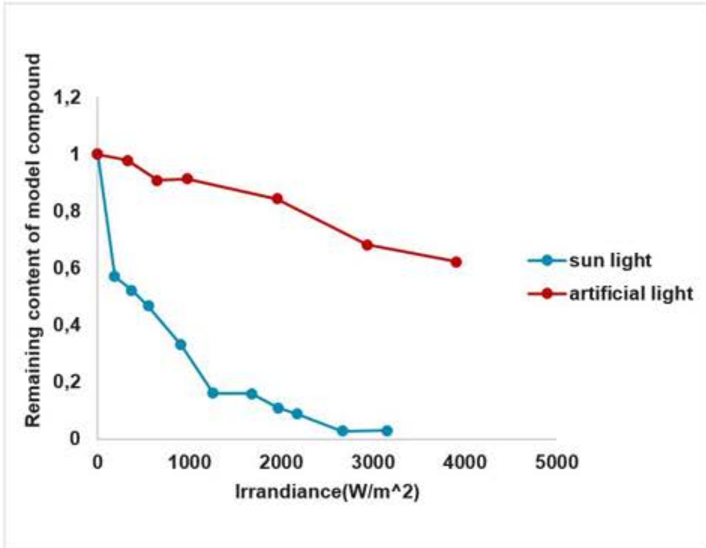
CS4: Results of laboratory experiments

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

Results of the individual technologies

- Coagulant effectively removes TSS
- The adsorption of VAC is more efficient if it goes prior to any chemical process → Minor change in our initial design
- The AOP effectively degrades organic matter when used both under solar or artificial light
- More results will be available the upcoming weeks



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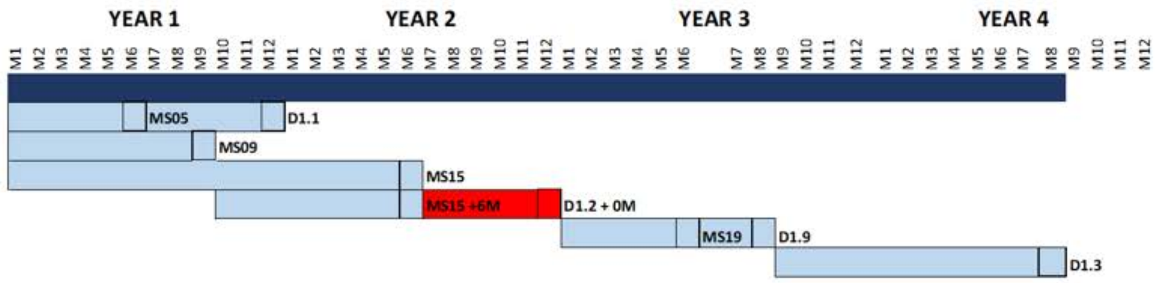
CS4: Subtask 1.2.4 – Timeline

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

T1.2.4 - Reuse of fruit processing wastewater in Nafplio
Baseline conditions assessed
Design of pilot system
Laboratory experiments
Pilot system operational (Filtration, AOP, SBP)
Start-up & results
Best practices for water recycling



→ **Pilot system (filtration, AOP and SBP) is operational**

→ **Enough time to complete the pilot experiments**

Legend
Task/Subtask
Activity as planned
Postponed activity
Delay of activity

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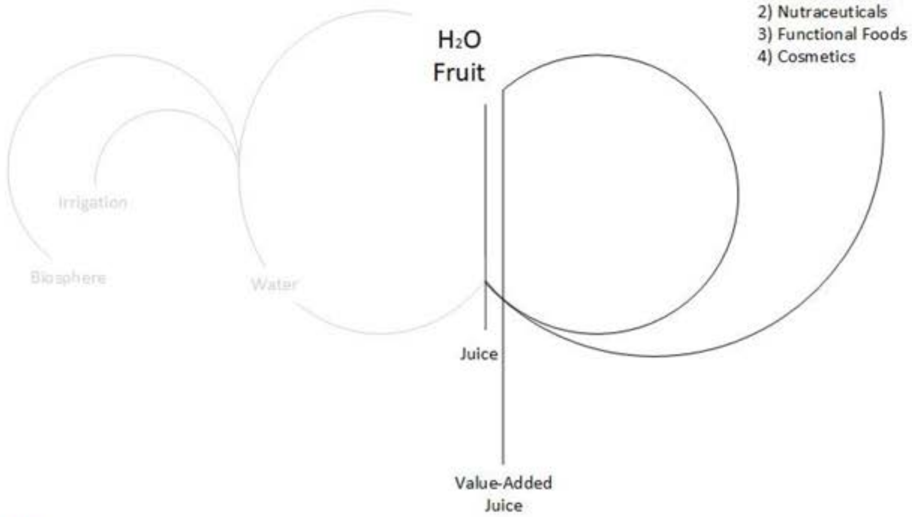
CS4: Subtask 1.4.3 Status/progress

Subtask: **1.4.3 Recovery of high-added-value compounds (antioxidants) in Nafplio**
Baseline technology: **No recovery**

Ultimate solution to foster circular economy:



TRL: **5 → 7**

Capacity: **10 m³/d**

Quantifiable target: **Recovery of polyphenols: 50-70%**

Status/progress:

- **Lab scale experiments completed**
- **Pilot unit under construction**

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CS4: Pictures/videos of the new technologies

Subtask: 1.4.3 Recovery of high-added-value compounds (antioxidants) in Nafplio

Lab scale – Dynamic adsorption

Static adsorption

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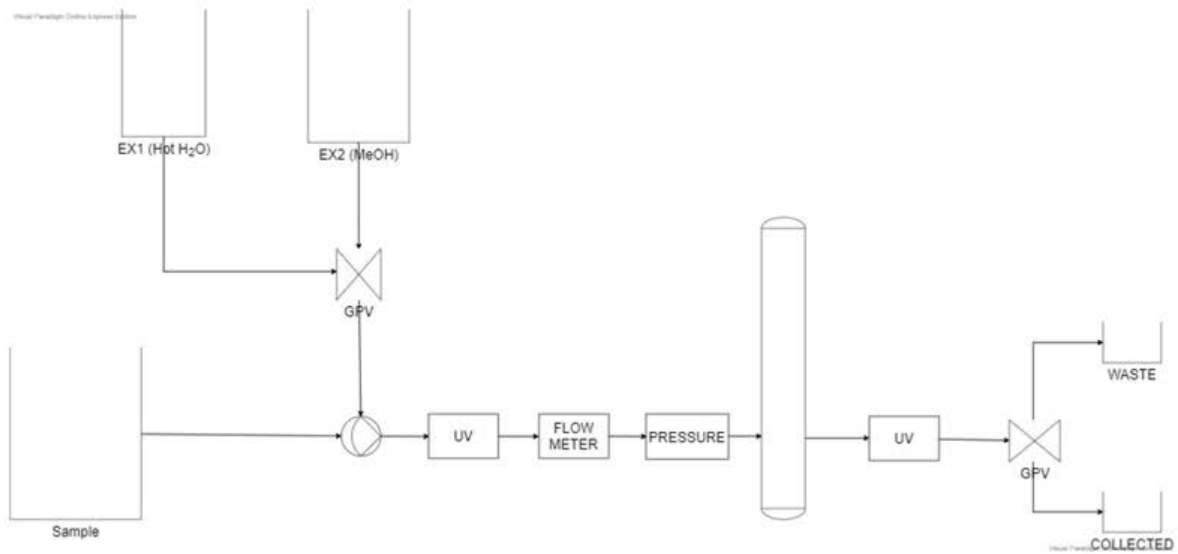
CS4: Operational procedures and methodologies

Subtask: 1.4.3 Recovery of high-added-value compounds (antioxidants) in Nafplio



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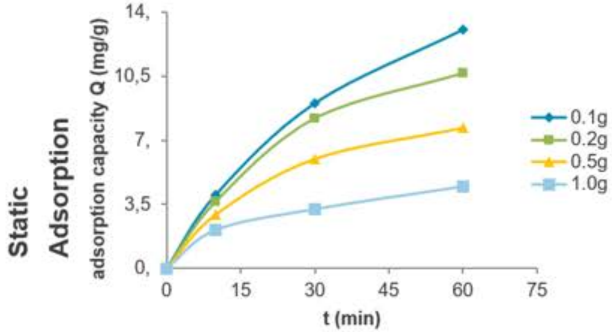
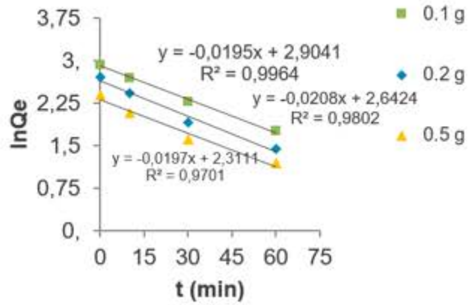
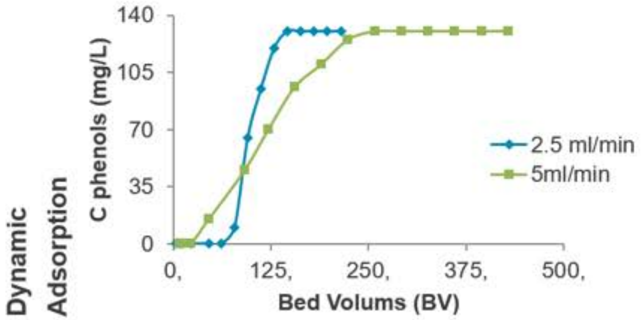
CS4: Results of the laboratory experiments

Subtask: 1.4.3 Recovery of high-added-value compounds (antioxidants) in Nafplio





maximum adsorptive capacity (Q): 23 g of polyphenols per kg of resin for the FPX 66 resin



The breakthrough curves showed that 1.7 m^3 of wastewater can be treated per kg of resin per 10 cycles

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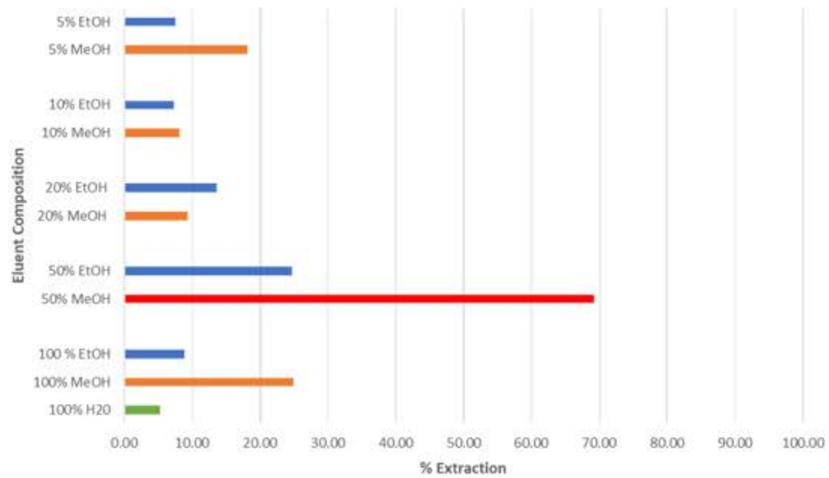
CS4: Results of the laboratory experiments

Subtask: 1.4.3 Recovery of high-added-value compounds (antioxidants) in Nafplio

- Static extraction experiments were performed employing hot water and organic solvents
- Water-methanol mixture (50:50 b.v.) yielded **69% polyphenols recovery**

- Currently working on dynamic extraction experiments,
- Aiming to optimise:
  - experimental conditions and
  - solvent recovery and reuse strategy



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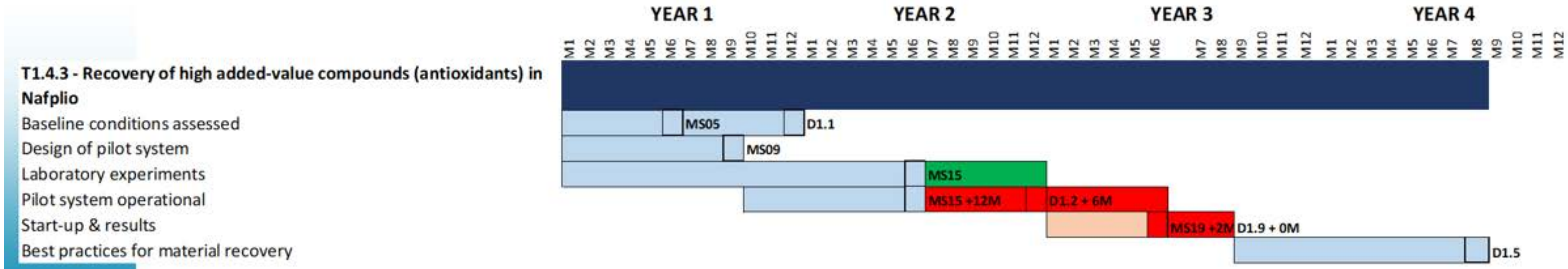
CS4: Subtask 1.4.3 – Timeline

Subtask: 1.4.3 Recovery of high-added-value compounds (antioxidants) in Nafplio



→ Pilot system expected to be operational in November 2022 (M30)

→ Extension of lab-scale experiments to accelerate pilot start-up and optimisation phases

→ Still enough time to complete the pilot experiments

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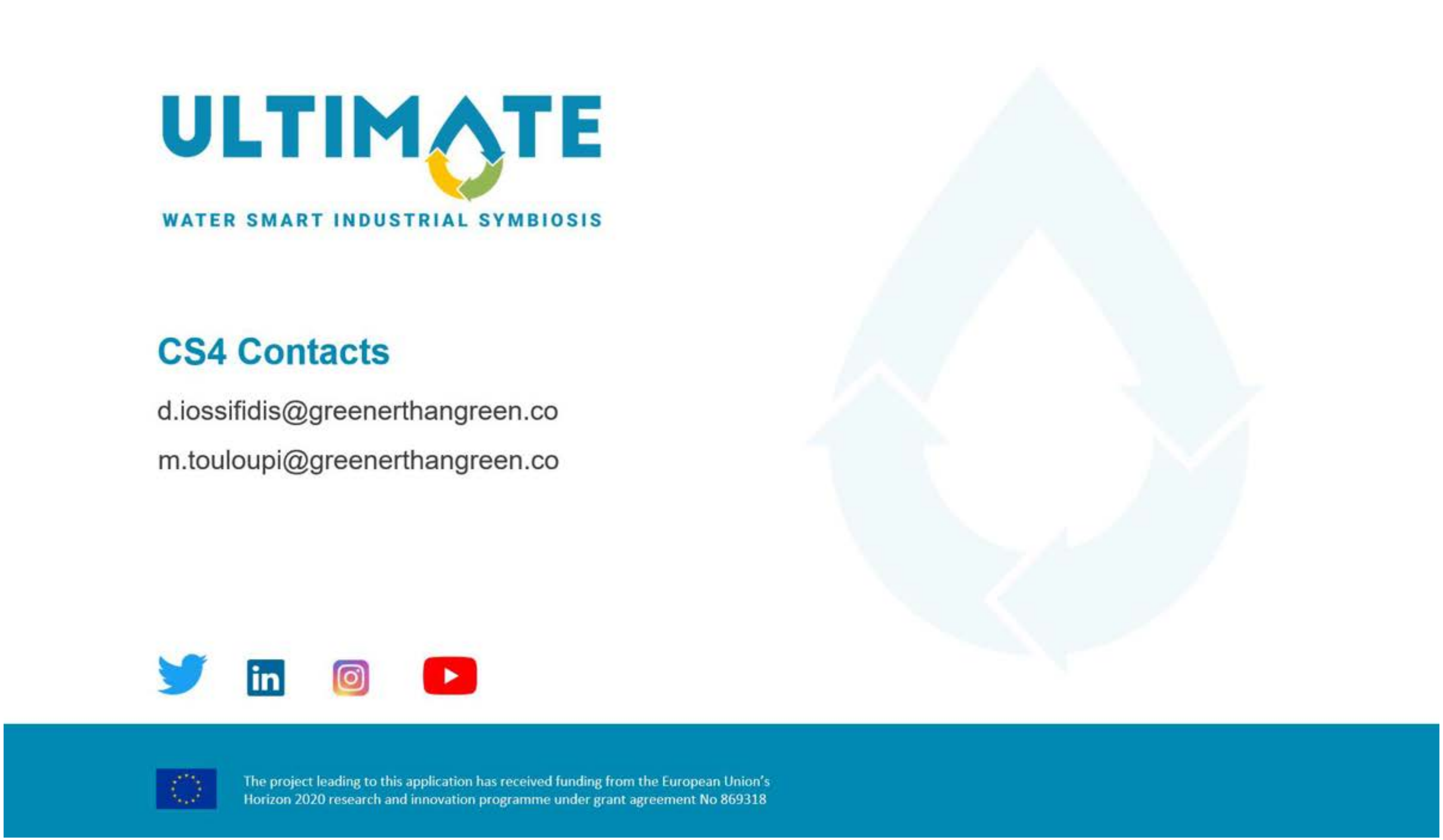

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2.5. CS5: Lleida

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
5	1.2.5	(NF + RO) + (AOP + UV)	100%	100% / 75%	100%	20; 25
	1.3.2	AnMBR	100%	100%	25%	25
		ELSAR	100%			30
		SOFC		100%	50%	26
	1.4.4	Concept study: Recovery nutrients from digestate; fertigation stategies	No pilot plant --> excluded from D1.2			
		Solar-driven hydrothermal carbonisation demo plant	100%	100%	100%	24

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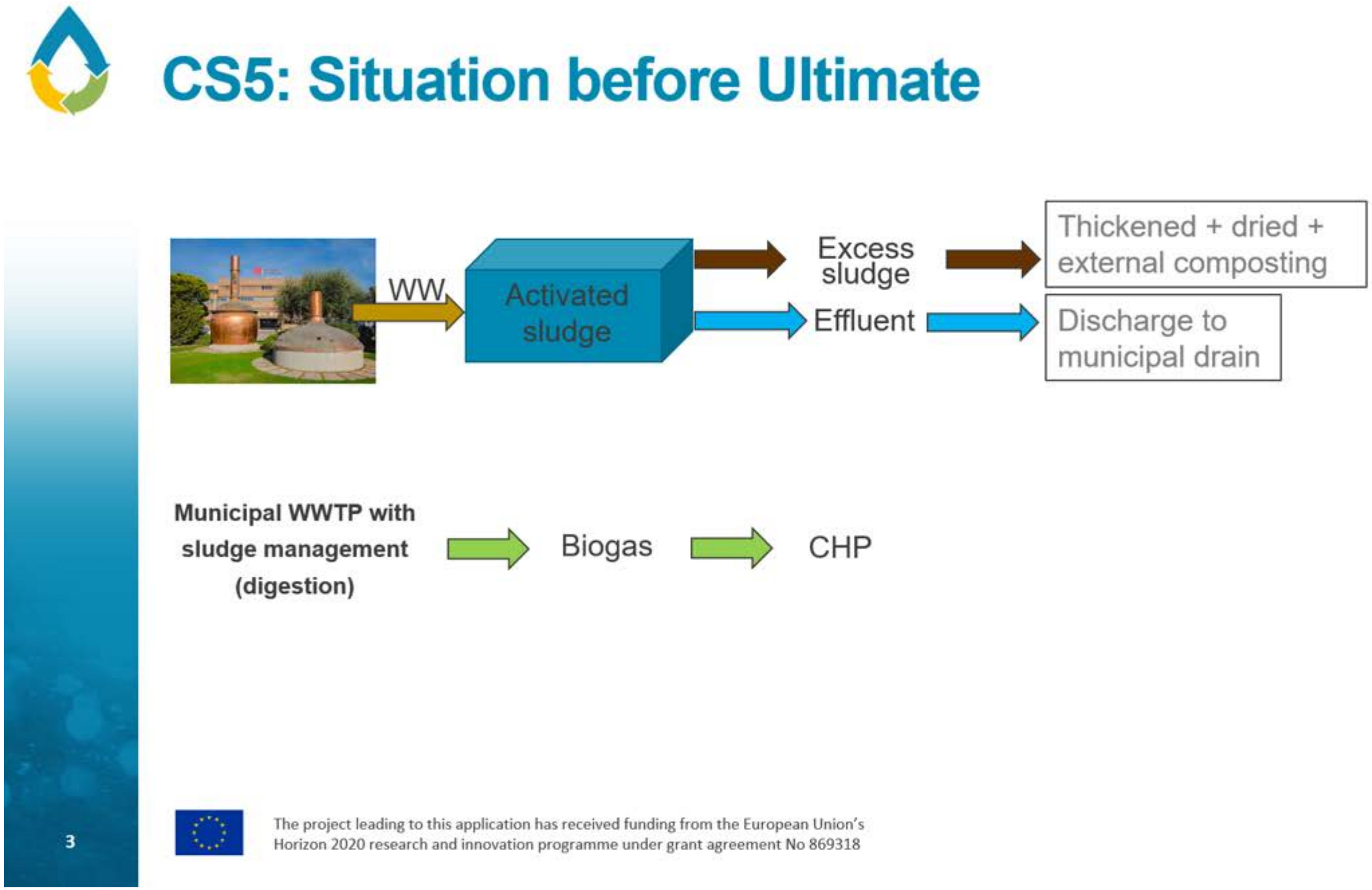

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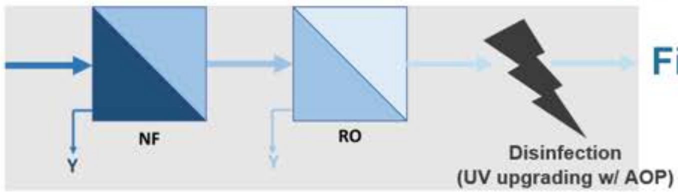
CS5: Subtask 1.2.5 Status/progress

Subtask: 1.2.5 Reuse of brewery wastewater as process water

Baseline technology: no water reuse so far (only wastewater treatment with activated sludge process and subsequent discharge to the municipal drain)

Ultimate solution to foster circular economy: membrane-based technologies, disruptive disinfection/AOP technologies

Effluent from secondary treatment



Fit-for-purpose water for cooling towers

TRL: 7 → 9

Capacity: 50 m^3/d

Quantifiable target: 4200-4600 m^3/a for cooling towers; 10-15% reduction of freshwater via reuse of treated water

Status/progress:

- Detailed design completed
- Existing plants under assembling and connection.
- UF & RO: operational
- AOP & UV: expected start-up in June 22 (M25)

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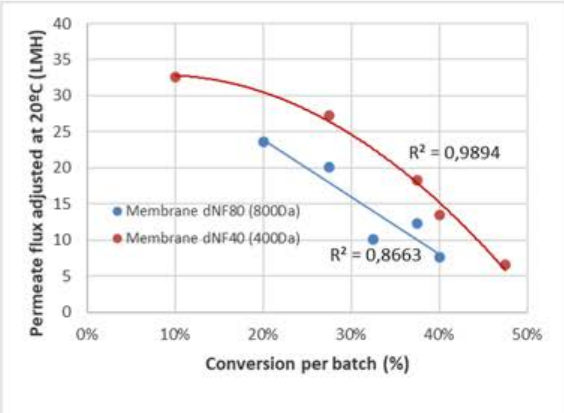
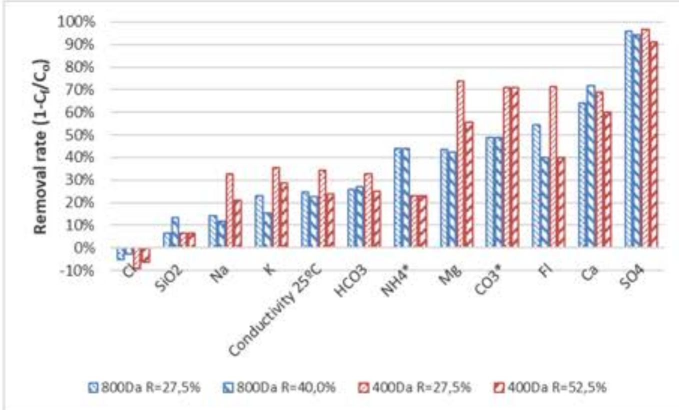
CS5: Results of laboratory experiments

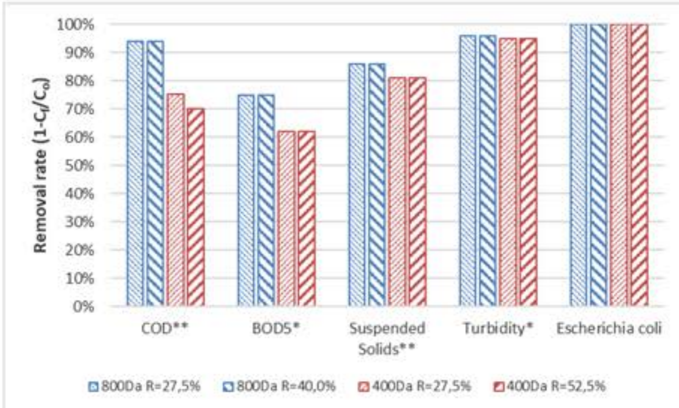
Subtask: **1.2.5 Reuse of brewery wastewater as process water**

Conclusions from previous lab-scale tests:

- NF is a valid technology for achievement of regulatory requirements, but for salinity removal a RO step is needed.
- 800Da is an enough membrane cut-off.
- Conversion should be kept as lower as possible to optimize filtration performance.







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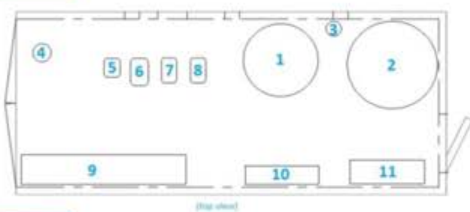
CS5: Pictures of NF & RO pilot system

Subtask: 1.2.5 Reuse of brewery wastewater as process water

Nanofiltration demo plant.

Composed by:

1. Feed tank
2. Permeate tank
3. Amiad strainer
4. Membrane module
5. CIP circulation pump
6. Circulation pump
7. Feed pump
8. Backwash pump
9. Chemical cabinets
10. Panel PC
11. Compressor



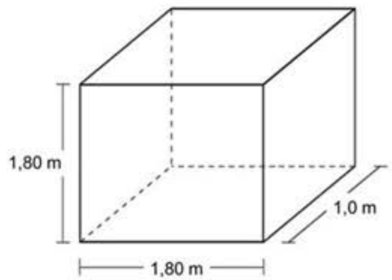
Dimensions:
6,0m x 2,4m x 2,4m

Reverse osmosis demo plant.

Composed by:

- Electrical cabinet
- 1 buffer tank
- 1 pressure vessel (2,5" membrane)
- 1 fabric filter
- 2 feeding pumps
- Several rotameters and manometers

Dimensions:



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CS5: Operational procedures and methodologies

Subtask: **1.2.5 Reuse of brewery wastewater as process water**

Analytical plan

PARAMETER	INPUT WATER		OUTPUT NF / INPUT RO		OUTPUT RO	
	Motivation	Frequence	Motivation	Frequence	Motivation	Frequence
"Legionella" sp	Performance NF	Weekly	Performance RO and NF	Weekly	RD 1620/2007 (absence)	Weekly
Nematode eggs	Performance NF	Weekly	Performance RO and NF	Weekly	RD 1620/2007 (<1 unit/10L)	Weekly
"Escherichia coli"	Performance NF	Weekly	Performance RO and NF	Weekly	RD 1620/2007 (absence)	Weekly
Suspended solids	Performance NF	Weekly	Performance RO and NF/ requirement RO	Weekly	RD 1620/2007 (<5 mg/L)	Weekly
Turbidity	Performance NF	Weekly	Performance RO and NF/ requirement RO	Weekly	RD 1620/2007 (< 1NTU)	Weekly
Conductivity @ 25ºC	Performance NF	Weekly	Performance RO and NF	Weekly	Required by cooling tower	Weekly
BOD5	Performance NF	Weekly	Performance RO and NF/ requirement RO	Weekly	UE 2020/741	Weekly
COD	Performance NF	Weekly	Rendimiento NF	Weekly	-	Weekly
pH	Requirement NF	Weekly	Required by RO step	Weekly	Required by cooling tower	Weekly
Alcalinity	-	0	-	0	Required by cooling tower	Weekly
Hardness	-	0	-	0	Required by cooling tower	Weekly
Chlorine	-	0	-	0	Required by cooling tower	Weekly
Ion composition	-	0	Descaling needs	1,5 months	-	0

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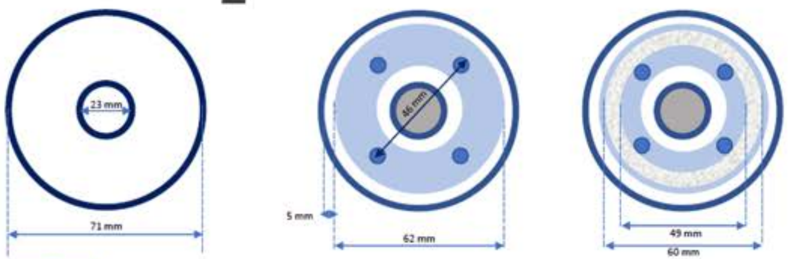
CS5: Development of AOP & UV test device

Subtask: 1.2.5 Reuse of brewery wastewater as process water

1. Photocatalytic reactor with support and first PLA prototypes adapted to the geometry of existing UV lamp.



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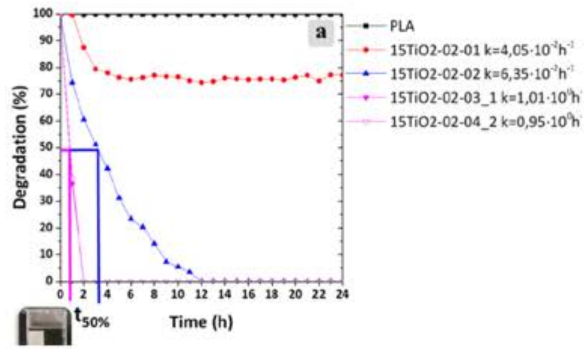
2. Design of ceramic filaments, printibles and sinterables, with high photocatalytic performance, adapted to the geometry of existing UV lamp.



Photodegradation of Methyl orange during 24h of sunlight exposition to rectangular TiO_2 membranes

3. Batch tests monitoring diclofenac degradation with synthetic and real water (To be done).

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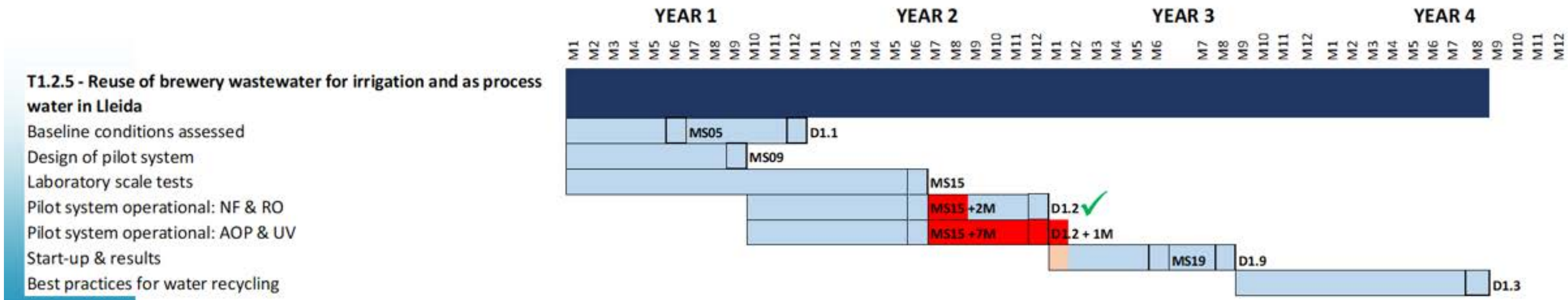
CS5: Subtask 1.2.5 – Timeline

Subtask: 1.2.5 Reuse of brewery wastewater as process water



NF & RO are operational

AOP & UV expected to be operational in June 2022 (M25)

→ Still enough time to complete the experiments

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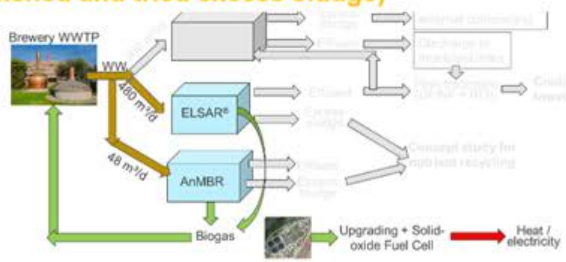
CS5: Subtask 1.3.2 Status/progress

Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell

Baseline technology: no energy production so far (only wastewater treatment with activated sludge process and subsequent composting of thickened and tried excess sludge)

Ultimate solutions to foster circular economy:

- Anaerobic membrane bioreactor (AnMBR),
- Electrostimulated anaerobic reactor (ELSAR),
- Solid oxide fuel cell (SOFC)



TRL: 7 → 9 (AnMBR); 5 → 7 (ELSAR); 7 → 9 (SOFC)

Capacity: 48 m³/d (AnMBR); 480 m³/d (ELSAR); 10 Nm³/d (SOFC)

Quantifiable targets: 20.000 m³ biogas/a (AnMBR); 200.000 m³ biogas/a (ELSAR); 4000-12.000 kWh_{el}/a (SOFC) >100 % energy recovery

Status/progress:

- Running detailed design: online monitoring system.
- Commissioning: AnMBR & SOFC, (both are installed being commissioning imminent)
- Waiting for building license: ELSAR

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CS5: Pictures of the new technologies

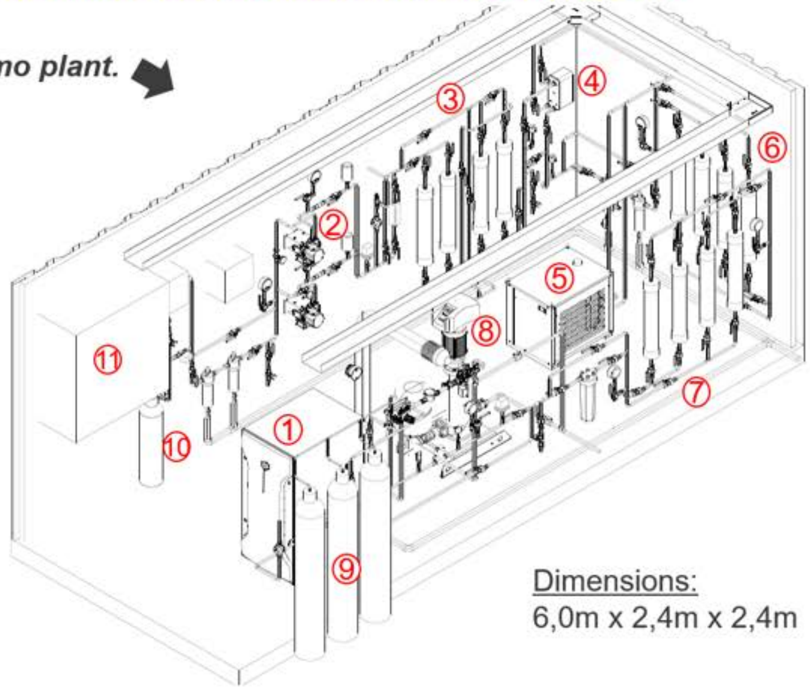
Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell

Solid-oxide fuel cell.
Suplier Solid Power; Model BlueGen BG-15.
Power output 0,5-1,5 kWe. Electrical efficiency > 57%.

Solid-oxide fuel cell demo plant.

Composed by:

1. Fuel Cell
2. Vacuum pumps
3. Desulphuration filters
4. Heat exchanger
5. Chiller
6. Dehumidification filters
7. Activated carbon filters
8. Pressure pump
9. Emergency biogas supply
10. Nitrogen gas
11. Electrical cabinet / PC



Dimensions:
6,0m x 2,4m x 2,4m

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CS5: Pictures of the new technologies

Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell

SOFC pilot plant installed in WWTP Lleida

Pending:

1. Connections to the WWTP:
    1. Biogas,
    2. Power supply
    3. Tap water
    4. Drainage
    5. Compressed air
    6. Signal communication & internet
2. Industrial gases: N_2 and "synthetic biogas" (CH_4+CO_2)
3. Paneling on the 6m x 2,5m external side
4. Safety electronic integration (galvanic isolation)
5. Safety inspection
6. Cold start-up (air)
7. Final integration of fuel cell
8. Hot start-up (biogas)

→ Operation

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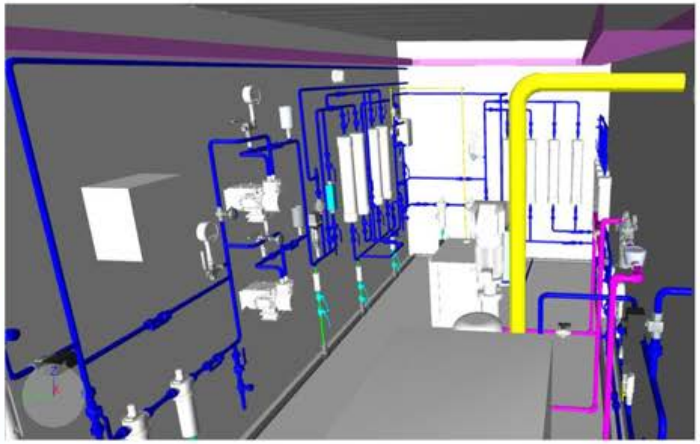
CS5: Pictures of the new technologies

Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell



What was intended to do: 3D view of the SOFC pilot plant in engineering project

What has been done: real picture of the SOFC pilot plant (taken April 2022)

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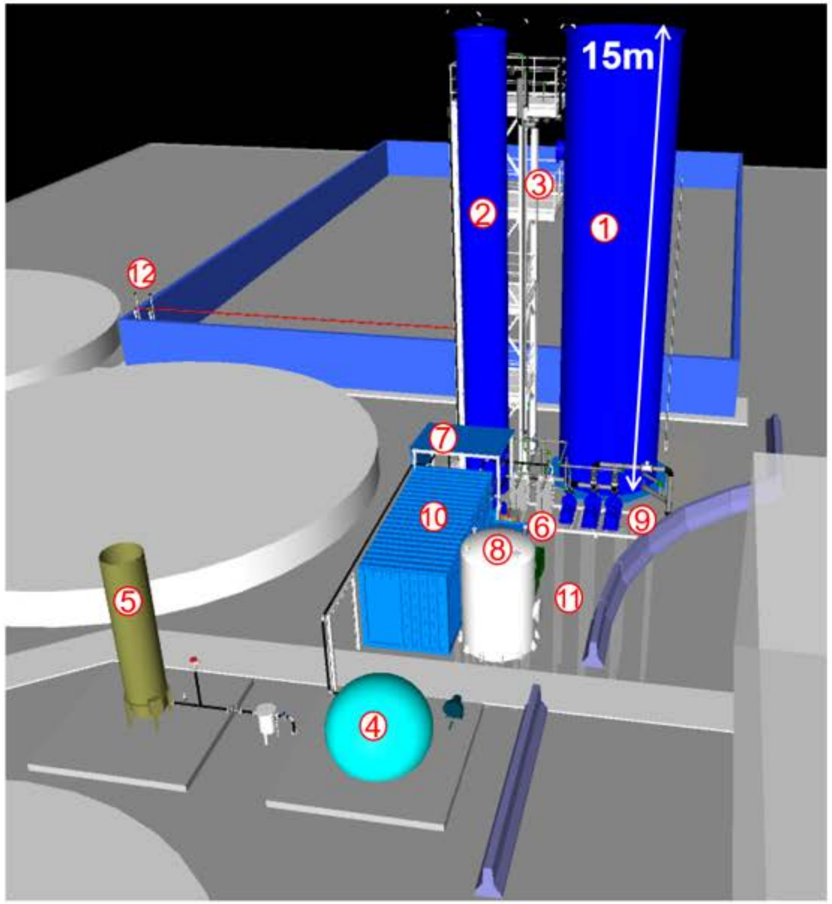
CS5: Pictures of the new technologies

Subtask: Electrostimulated anaerobic reactor (ELSAR®)

- **Capacity**
  - *Input Brewery Wastewater*
  - *Flow 20 m³/h, OLR 2 Tn COD/d*
- **Reactor features**
  - *Total Volume Reactor 140m³*
  - *Ø 3,5m; Water height 15m*
  - *Mesophilic range (30 - 37ºC)*
- **Expected results**
  - *90% COD removal*
  - *31 Nm³ biogas/h*
  - *Energy surplus*



Composed by:

1. ELSAR reactor
2. Buffer reactor
3. Stairs structure
4. Gazometer
5. Flare
6. Heat exchangers
7. Chiller
8. Chemical storage
9. Pumping station
10. Office, lab, store
11. Foundation
12. Feeding pumps

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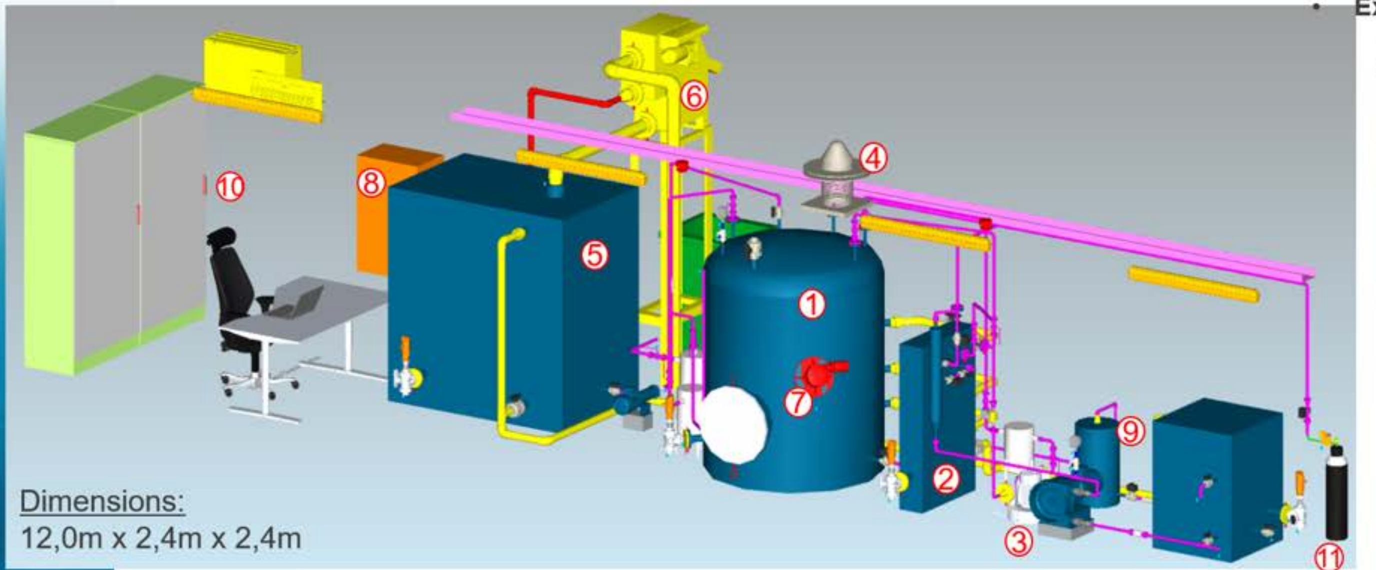
CS5: Picture of the AnMBR

Subtask: Anaerobic Membrane Bio Reactor (AnMBR)



- **Capacity**
  - *Input Industrial Wastewater*
  - *Flow 2 m^3/h*
  - *OLR 200 kg COD/d*
- **Reactor features**
  - *Total Volume Reactor $40m^3$*
  - *Mesophilic range (30 - 37ºC)*
- **Expected results**
  - *95% COD removal*
  - *3,5 Nm^3 biogas/h*

Composed by:

1. Biological reactor
2. Membranes
3. Blower and recirculation pumps
4. Ventilator
5. Buffer tank
6. Screen
7. Stirrer
8. Electrical cabinet
9. Backwash and permeate tanks
10. Office
11. Inert gas

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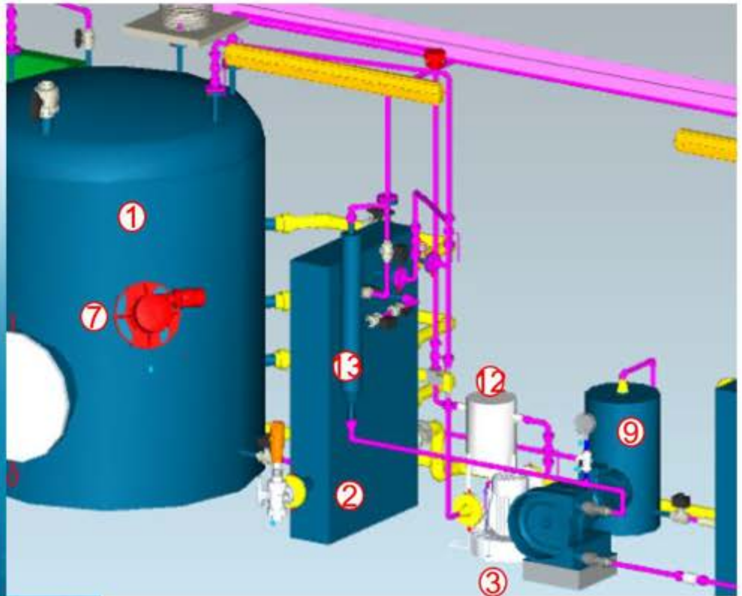
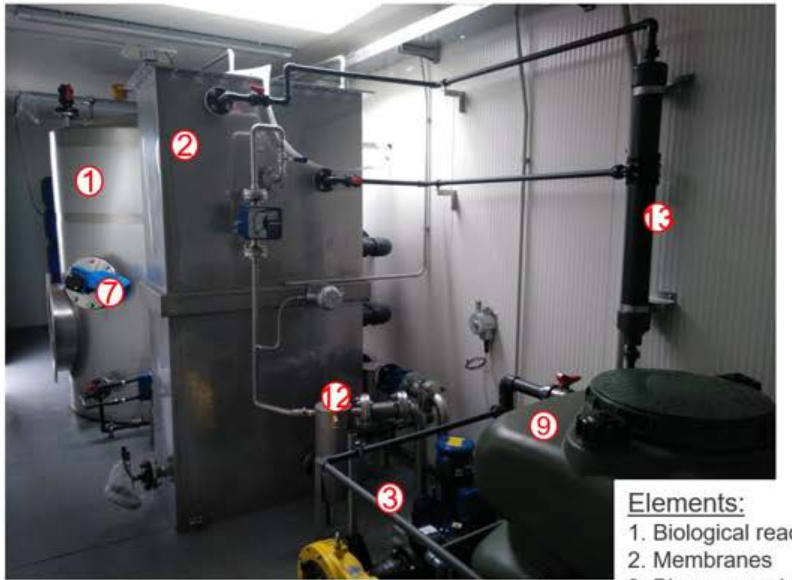
CS5: Pictures of the AnMBR

Subtask: Anaerobic Membrane Bio Reactor (AnMBR)



What was intended to do: 3D view of the AnMBR pilot plant in engineering project



What has been done: real picture of the AnMBR pilot plant (taken April 2022)

Elements:
1. Biological reactor
2. Membranes
3. Blower + recirculation pump
7. Stirrer
9. Backwash / permeate tanks
12. Condensates pot
13. Degassing unit

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CS5: Operational procedures and methodologies

Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell

SOFC

- **Monitoring of:**
  - Monthly analytical determination of biogas components (before entering the SOFC).
  - Online measuring of pressure, temperature and moisture before entering the SOFC.
  - Register of biogas consumption, produced energy, electrical energy consumption and water consumption.
- **Support:** Training and online support of the SOFC will be provided by the supplier during the first operation year.
- **Security measures:**
  - Excess air ventilation
  - 2 units of lower explosive limit (LEL) detector for CH_4
  - Flame arresters

ELSAR® and AnMBR

- **Monitoring of:**
  - Weekly analytical determination of produced biogas components and of treated wastewater.
  - Online measuring of fouling-linked parameters (only for AnMBR) as well as several operational parameters.
  - Operation without and with the electrochemical system, at different voltage (only for ELSAR®).
  - Register of chemical consumption, produced energy and electrical energy consumption.
- **Security measures:**
  - Excess air ventilation (only for AnMBR)
  - Lower explosive limit (LEL) detectors for CH_4 (only for AnMBR)
  - Flame arresters

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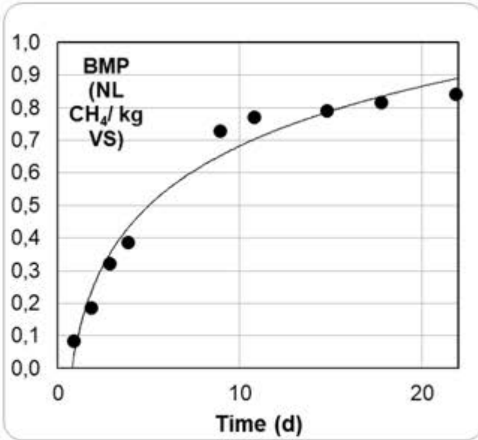
CS5: Laboratory results

Subtask: Electrostimulated anaerobic reactor (ELSAR®) and Anaerobic Membrane Bio Reactor (AnMBR)

- Exhaustive brewery wastewater characterization (1 month long)
- Biochemical methane potential (BMP) tests showing adequate anaerobic biodegradability. A potential of 0,31 Nm^3 CH_4/ removed kg COD was found. This result is consistent with other sources.
- Preliminary geotechnical study & basic design projects shows no technical limitations for proposed solutions (but a need for foundation & civil works)



PARAMETER	AVERAGE ± STANDARD DEVIATION	UNITS
COD (stirred sample)	5586±1732	mg/L
COD (settled sample)	4674±1765	mg/L
NH4	3±3	mg/L
NO3	2±1	mg/L
Total N	64±23	mg/L
Total P	17±4	mg/L
Sulphates	158±32	mg/L
Sulphur	<1	mg/L
Conductivity	2551±627	µS/cm
Total alkalinity	19,3±6,6	meq/L
Partial alkalinity	8,8±4,4	meq/L
Intermediate alkalinity	12,9±3	meq/L
Volatile fatty acids	15±3,6	mg Ac/L
pH	6,67±0,96	-log[H+]
Total suspended solids	199±99	mg/L
Volatile suspended solids	124±51	mg/L
% SSV	0,67±0,16	%
Settled solids	40±30	mg/L

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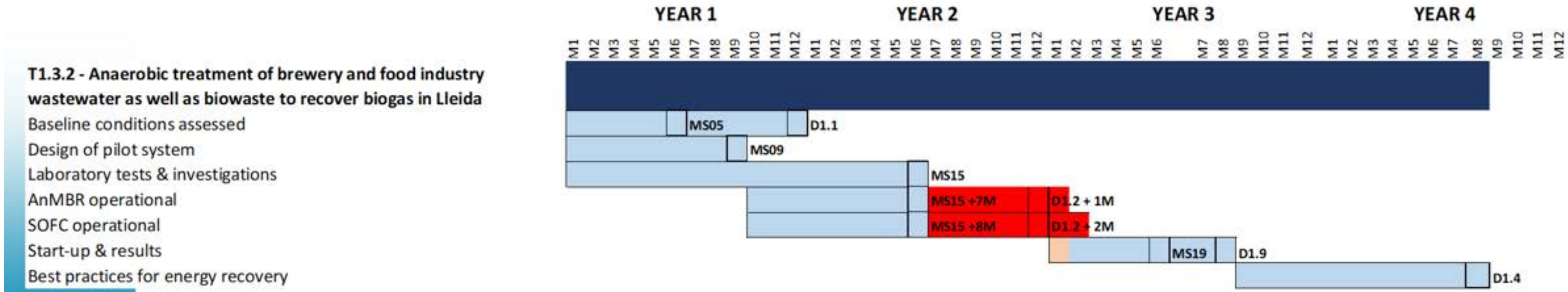
CS5: Subtask 1.3.2 – Timeline for AnMBR & SOFC

Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell



AnMBR & SOFC expected to be operational in June (M25) and July 2022 (M26)

→ Still enough time to complete the experiments

Legend
- Task/Subtask
- Activity as planned
- Postponed activity
- Delay of activity
- Extension of activity

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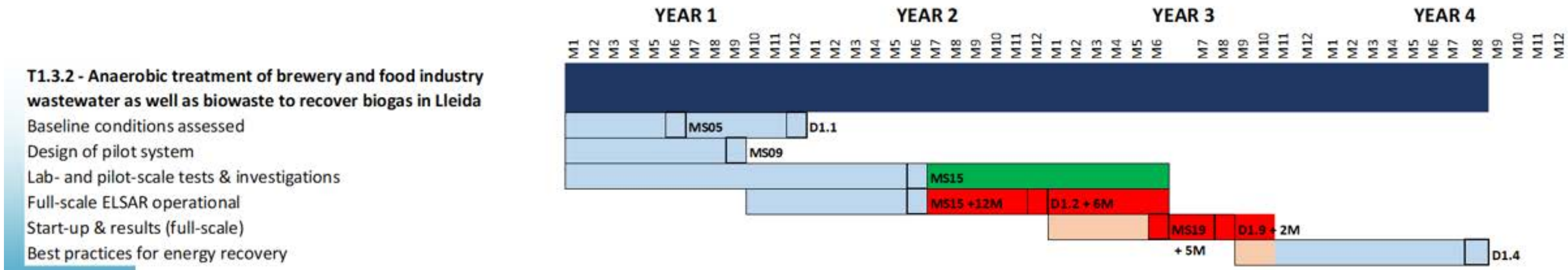
CS5: Subtask 1.3.2 – Timeline for ELSAR

Subtask: 1.3.2 Anaerobic pretreatment of brewery wastewater and electricity production via solid-oxide fuel cell



ELSAR (full-scale) expected to be operational in November 2022 (M30)

→ Extension of lab- and pilot-scale experiments to accelerate start-up and optimisation phases of full-scale ELSAR

→ Still enough time to complete the experiments

Legend

- Task/Subtask
- Activity as planned
- Postponed activity
- Delay of activity
- Extension of activity

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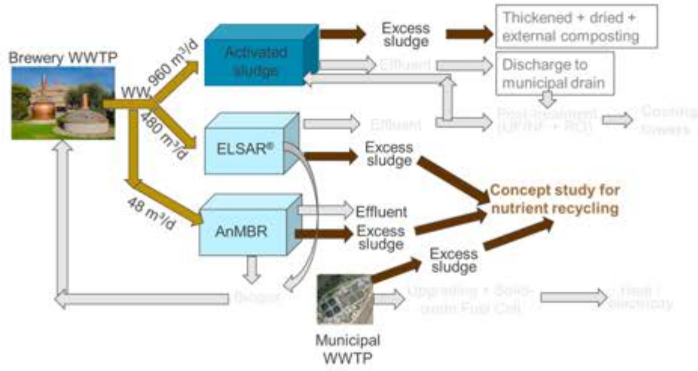
CS5: Subtask 1.4.4 Status/progress

Subtask: **1.4.4 Recovery of nutrients from brewery digestates**
Baseline technology: composting of thickened and tried excess sludge

Ultimate solution to foster circular economy:

1. STRUVITE / VIVIANITE
Feasibility of integration of Aqualia technologies and previous experiences

2. HYDROCHAR
Sludge and other potential solids: spent grain + yeast, *tbd;* Feasibility of integration and techno-economical comparison. Special focus on solar-based HTC technologies



TRL: **5 → 7** (concept study: material recovery)

Capacity: **P-recovery**: 6 t phosphorous/a; **Hydrochar:** 600 t (brewery)/a & 1600 t (WWTP)/a

Quantifiable target: 6 t phosphorus/a; 6% P recovery; 600 t hydrochar/a

Status/progress: Feasibility report under progress.

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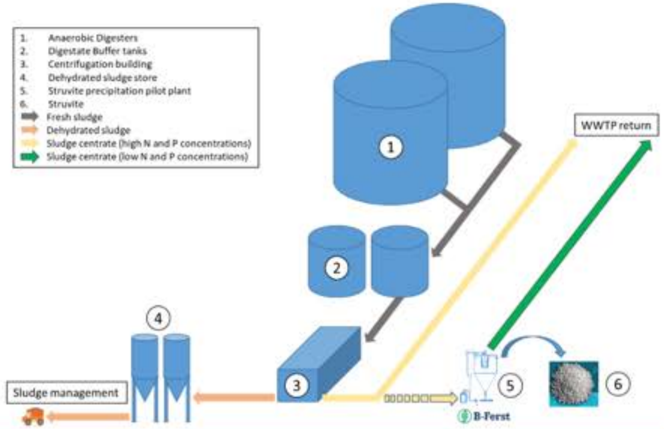
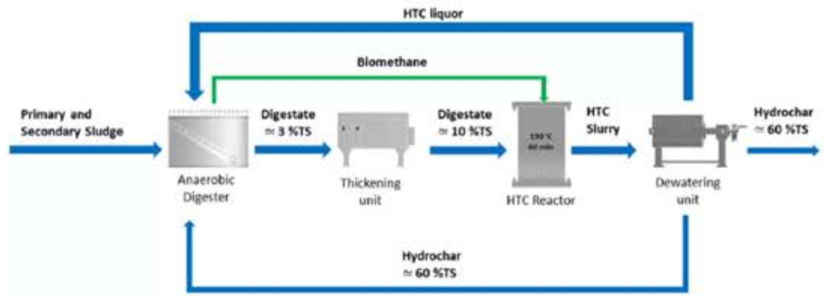
CS5: Concept study incl. solar pilot plant

Subtask: 1.4.4 Recovery of nutrients from brewery digestates





1. STRUVITE / VIVIANITE

- Potential of 6 T P/a in urban WWTP
- Feasibility of integration of Aqualia technologies and previous experiences

2. HYDROCHAR

- Potential sludge 600 T/a (brewery) & 1600 T/a (urban WWTP) (dry basis)
- Potential 1 GWh/a of effective solar energy used for HTC.
- Other potential solids: spent grain + yeast, *tbd*
- Feasibility of integration and techno-economical comparison

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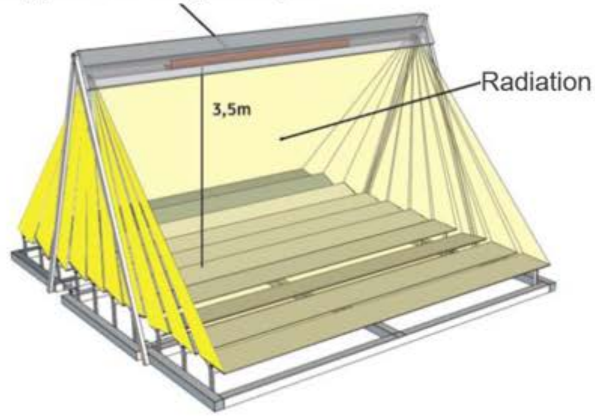
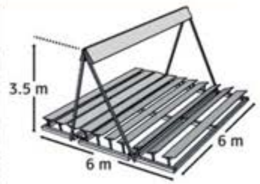
CS5: Pictures of the solar pilot plant

Subtask: 1.4.4 Recovery of nutrients from brewery digestates



What was intended to do: 3D view of the solar pilot plant in engineering project

Supplied power (based on max. typical climate data)	14,5 kWt
Net mirror surface	26,4 m^2
Footprint	36 m^2
Expected lifespan	20 years
Monitoring of energetic production & climatic data	Yes
Self-orientation of mirrors	Yes
Remote visualization	Yes



What has been done: real picture of the solar pilot plant (taken April 2022)

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CS5: Operational procedures and methodologies

Subtask: 1.4.4 Recovery of nutrients from brewery digestates

Concentrated solar pilot plant for sludge treatment

- **Monitoring of:**
  - Temperature
  - Moisture (for drying evaluation)
  - Volatile matter (for hydrolysis evaluation & carbonization)
  - *E. Coli*, *Samonella ssp.*, *Clostridium perfringens* ((for disinfection evaluation).
- **Evaluation of results:**
  - Monitored variables at different set temperatures will be contrasted with models
- **Mode:**
  - Batch tests
  - Development & test of a continuous system

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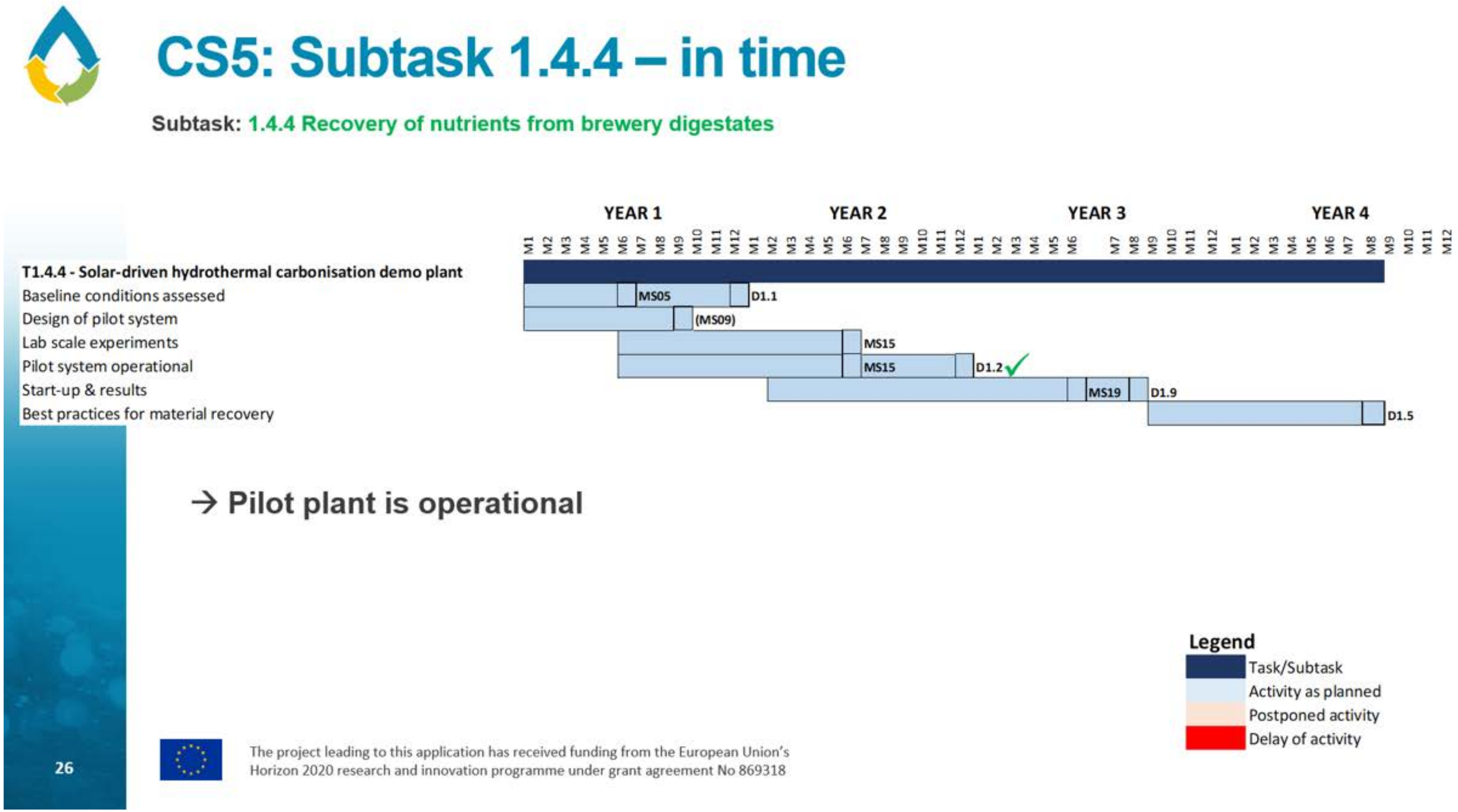

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ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS5 Contact

antonio.gimenez@fcc.es

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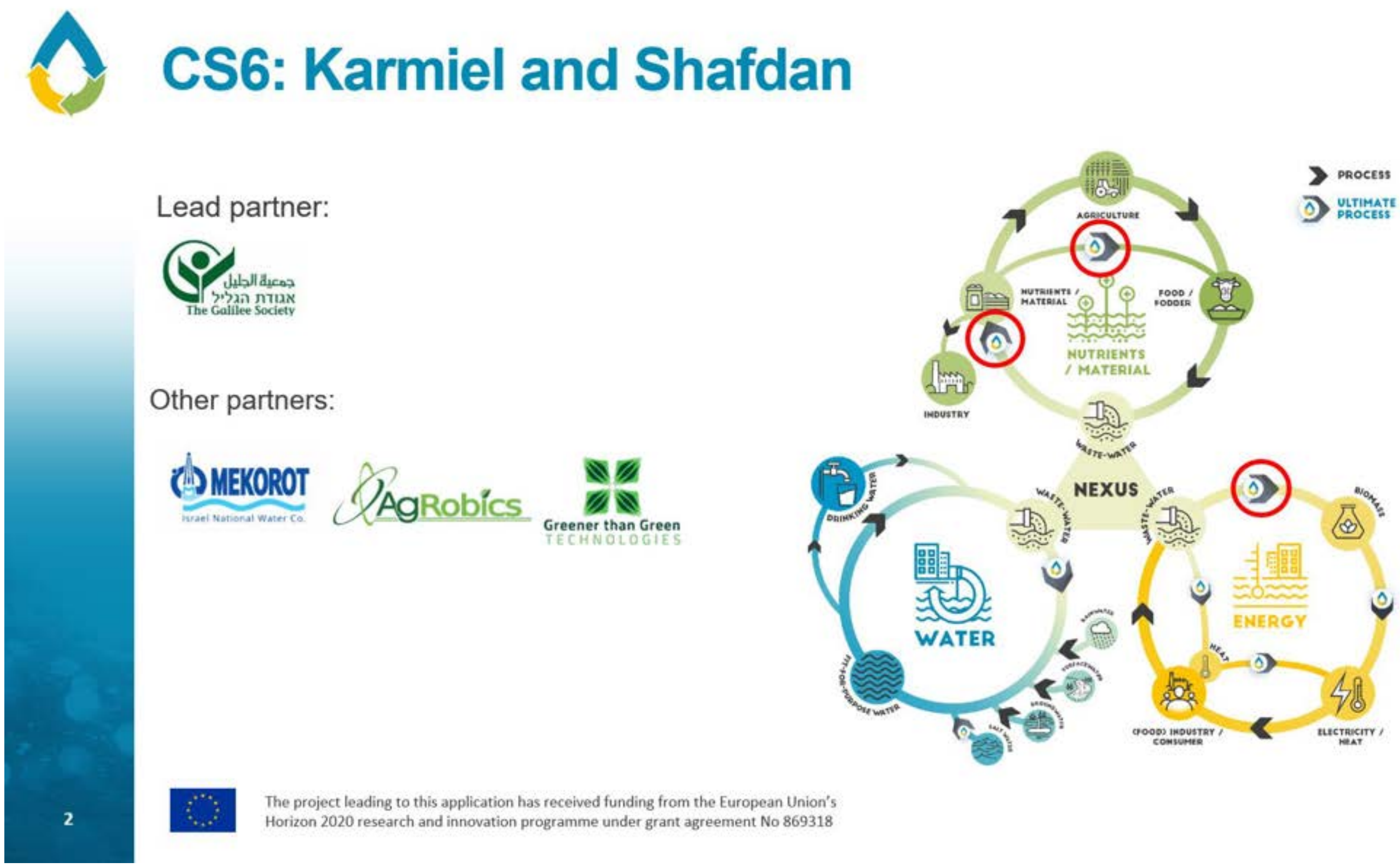
2.6. CS6: Karmiel & Shafdan

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
6	1.3.3	AAT Karmiel		100%	100%	24
	1.3.4	AAT + membrane filtration incl. PAC Shafdan	90%	90%		25
	1.4.5	Recovery polyphenols (pilot system: adsorption column)	90%			30



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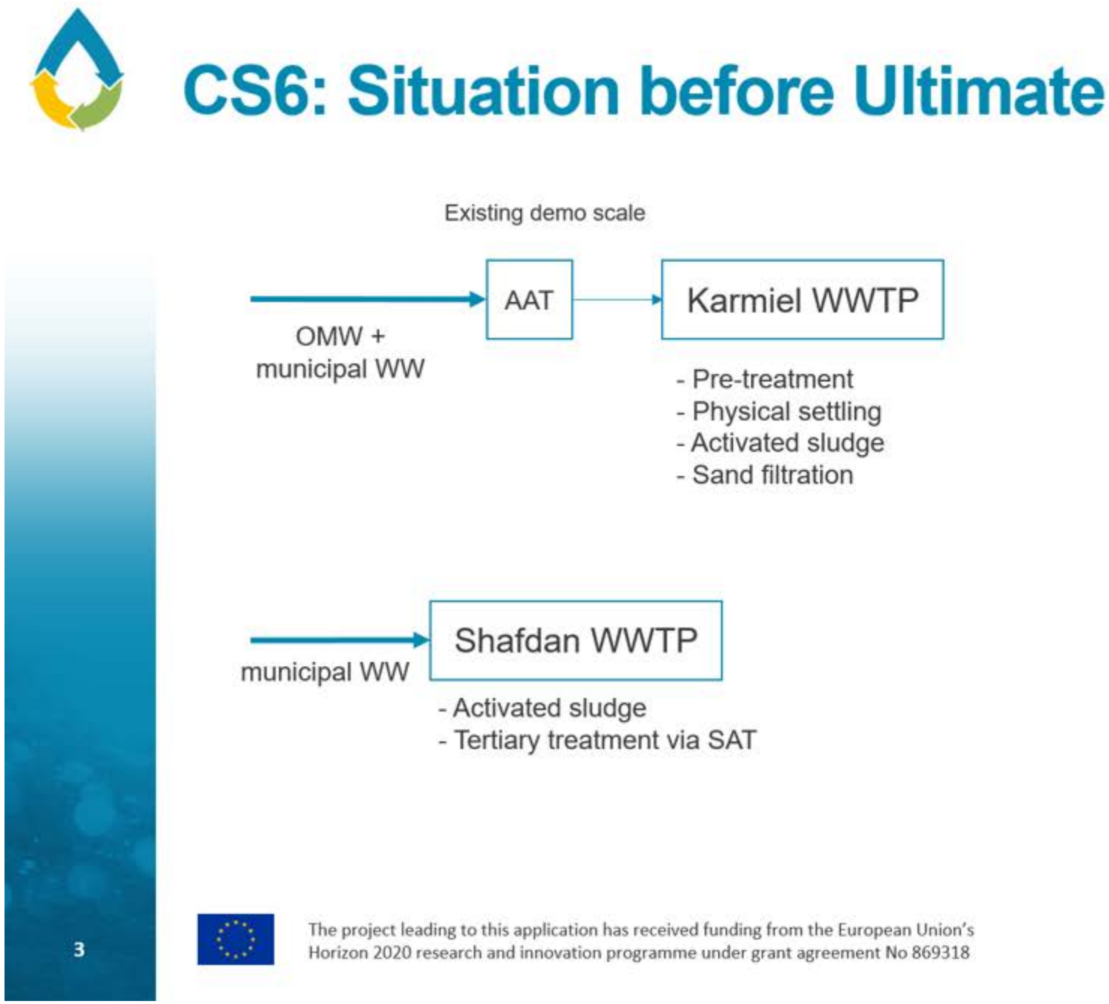
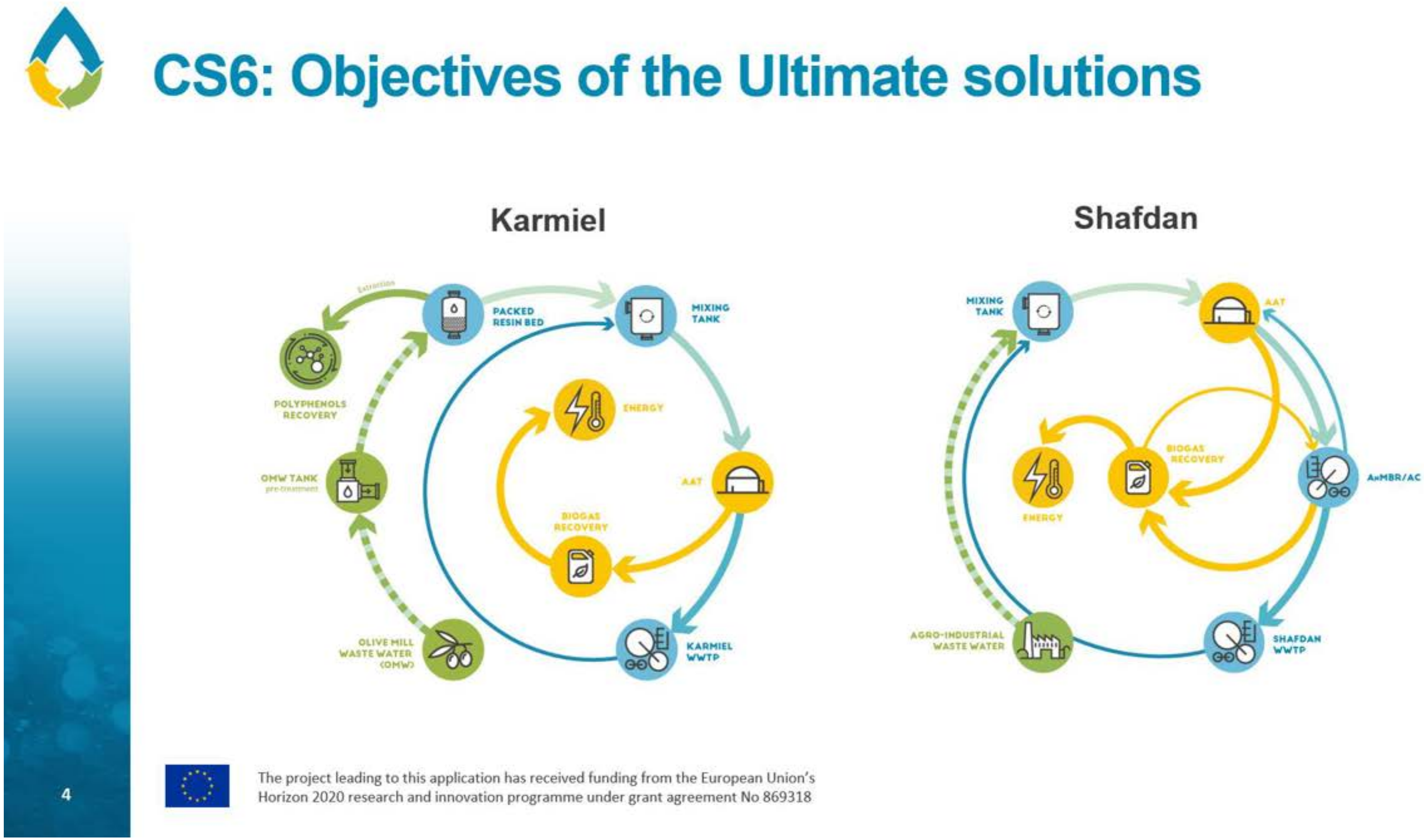
Horizon 2020 research and innovation programme under grant agreement No 869318



The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318



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Horizon 2020 research and innovation programme under grant agreement No 869318

CS6: Subtask 1.3.3 Status/progress - Karmiel

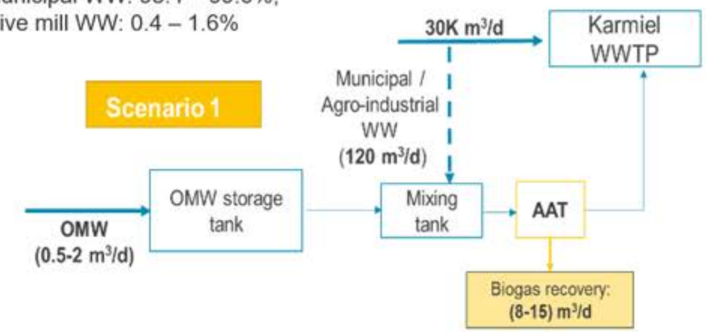
Subtask: 1.3.3 Biogas production from anaerobic pre-treatment of municipal and/or industrial wastewater in Karmiel

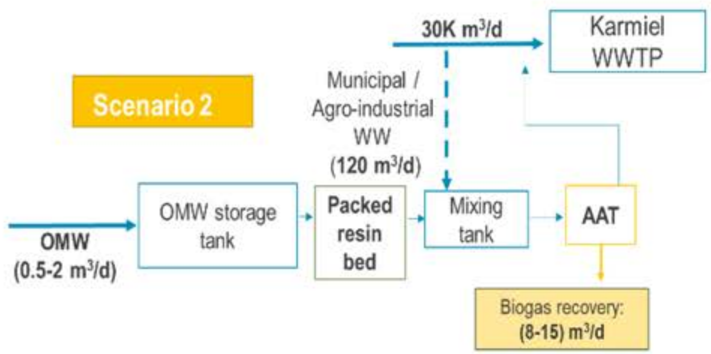
Baseline technology: Existing AAT demonstration plant

Ultimate solution to foster circular economy: Advanced Anaerobic Technology (AAT) for biogas production

Capacity: 120 m³/d **TRL:** 5 → 8

municipal WW: 98.4 – 99.6%;
olive mill WW: 0.4 – 1.6%





Quantifiable targets: 8-15 m³ biogas/d; 20-25% reduction of energy demand; 25% energy recovery

Status/progress:
- detailed design completed
- constructed and operational

5

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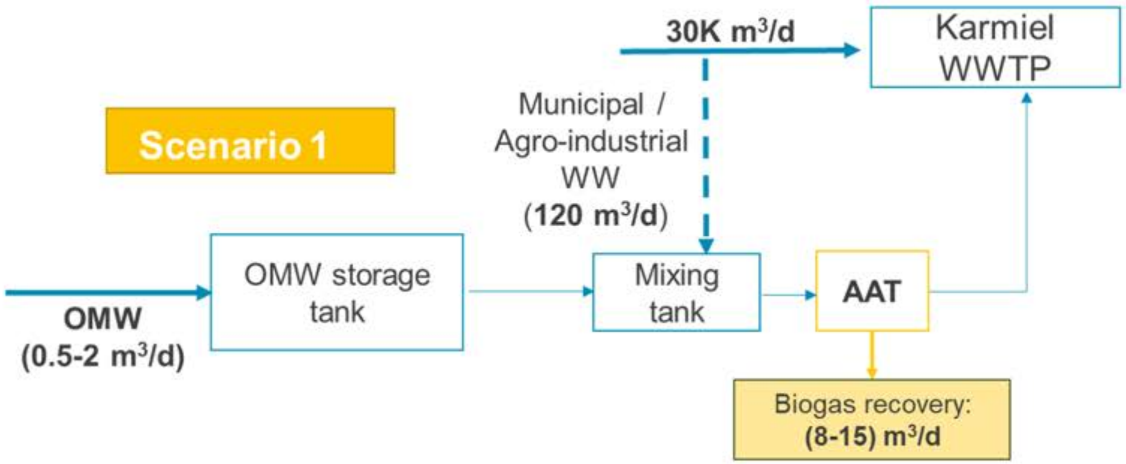
CS6: Current operational procedures and methodologies - Karmiel

Subtask: 1.3.3 Biogas production from anaerobic pre-treatment of municipal and/or industrial wastewater in Karmiel



AAT ... Advanced anaerobic treatment
OMW… Olive mill wastewater
WWTP... Wastewater treatment plant

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CS6: Picture of the high rate anaerobic reactor (AAT)

Subtask: 1.3.3 Biogas production from anaerobic pre-treatment of municipal and/or industrial wastewater in Karmiel

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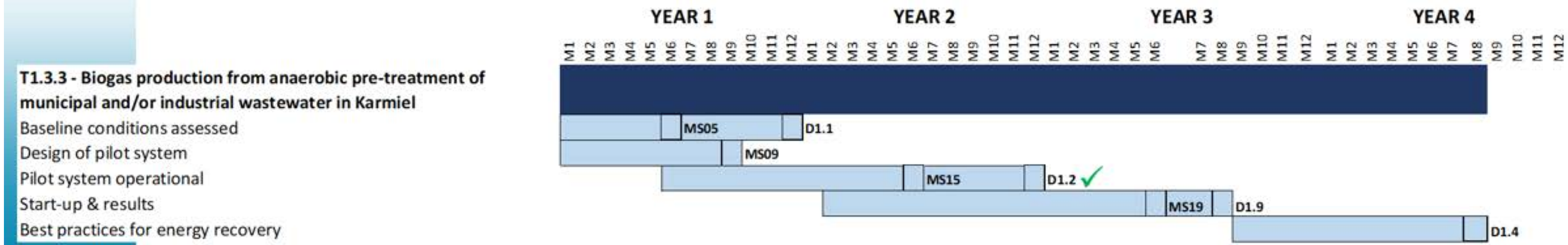
CS6: Task 1.3.3 is in time - Karmiel

Subtask: 1.3.3 Biogas production from anaerobic pre-treatment of municipal and/or industrial wastewater in Karmiel



→ Immobilised anaerobic high rate reactor (AAT) is operational

Legend
- Task/Subtask
- Activity as planned
- Postponed activity
- Delay of activity

8

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CS6: Subtask 1.3.4 Status/progress - Shafdan

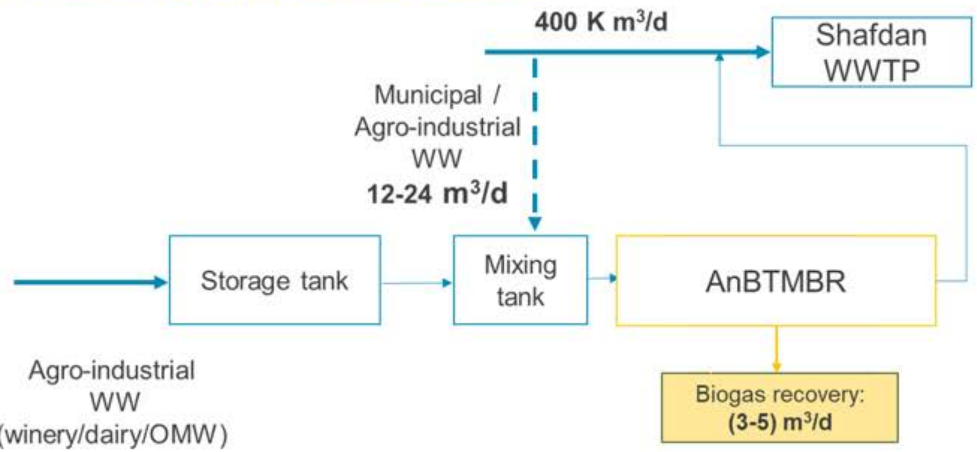
Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

Baseline technology: Biogas production via existing anaerobic digestion (AD)

Ultimate solution to foster circular economy: AAT with AC to prevent biomass inhibition

TRL: 5 → 7

Capacity: 12-24 m³/d



Quantifiable targets:
- 3-5 m³ biogas/d;
- 20-25% reduction of energy demand;
- 25% energy recovery

Status/progress:
- detailed design completed
- under construction

AnBTMBR ... Anaerobic biofilm treatment membrane bioreactor
OMW... …….. Olive mill wastewater
WWTP........... Wastewater treatment plant

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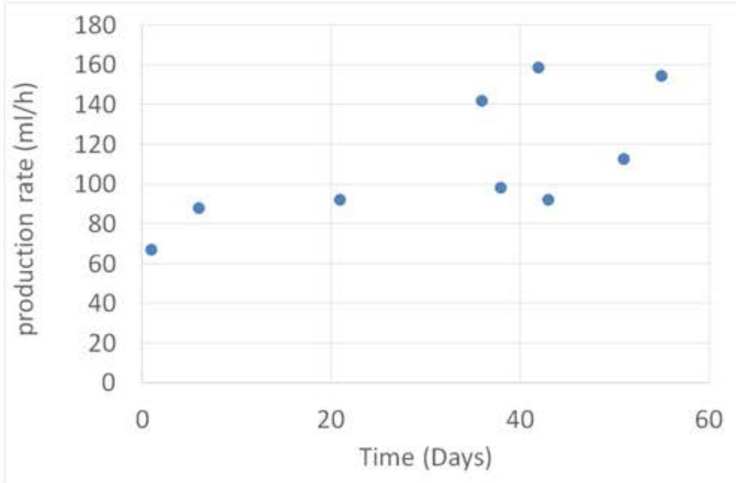
CS6: Results of the laboratory experiments

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

The lab-scale: The start-up of the system has been done two months ago. Below you can see the picture of the lab-scale system with the first preliminary results of rate of biogas production



10

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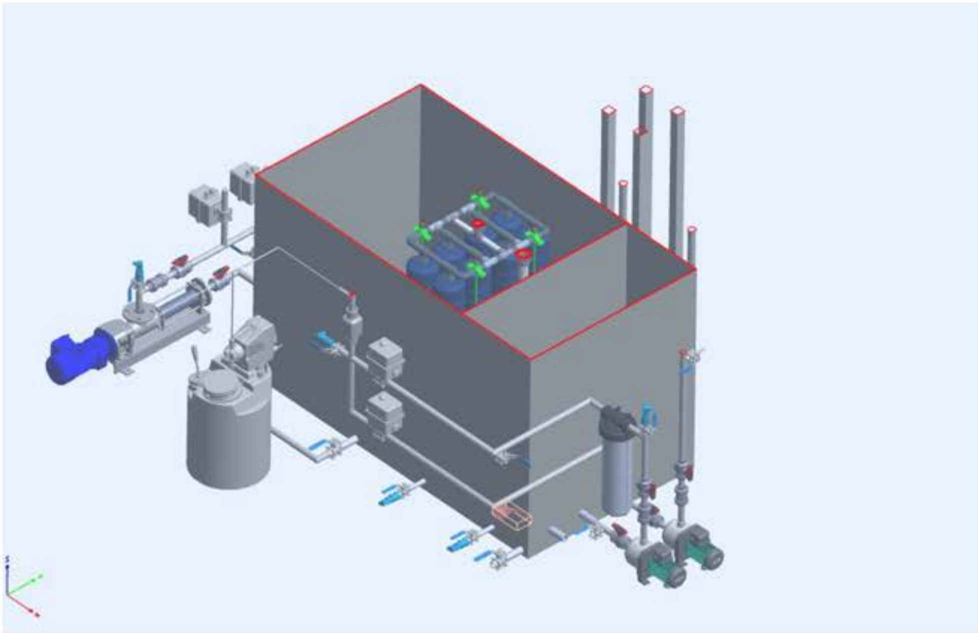
CS6: Pictures of the anaerobic pre-treatment system

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan



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CS6: Pictures of the anaerobic pre-treatment system

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

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CS6: Pictures of the anaerobic pre-treatment system

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

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CS6: Pictures of the anaerobic pre-treatment system

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

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CS6: Pictures of the anaerobic pre-treatment system

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

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CS6 Video: construction of anaerobic pre-treatment system

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

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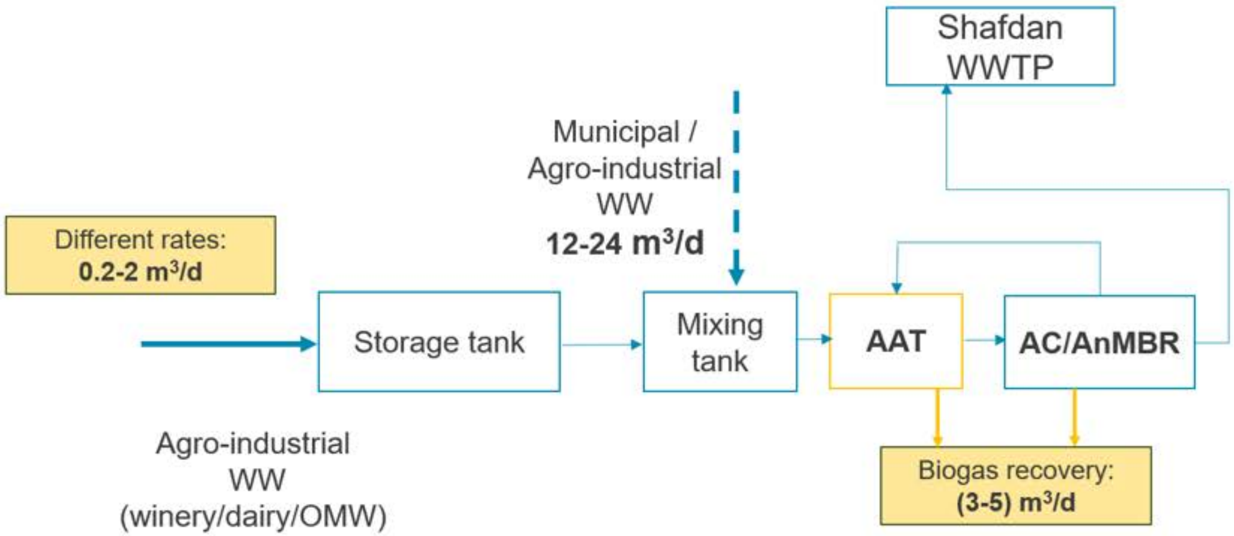
CS6: Operational procedures and methodologies (Shafdan)

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan



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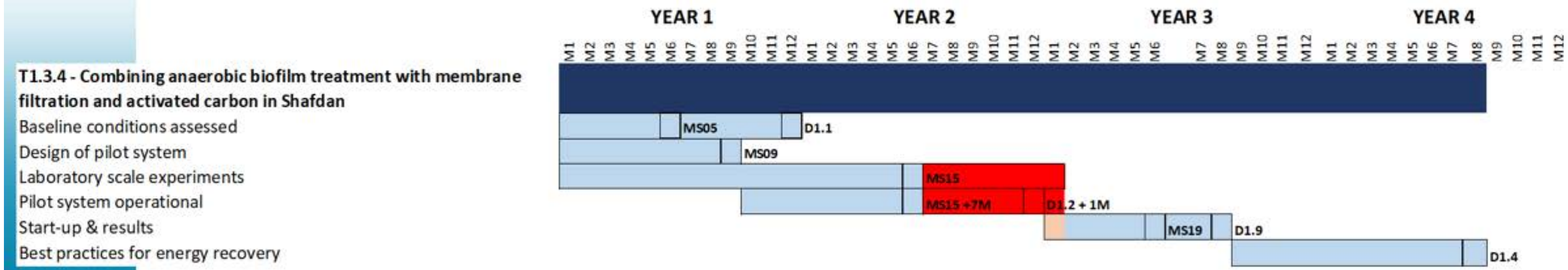
CS6: Task 1.3.4 – Timeline - Shafdan

Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan



AnTBMBR expected to be operational in June 2022 (M25)

→ Still enough time to complete the experiments

Legend

- Task/Subtask
- Activity as planned
- Postponed activity
- Delay of activity

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CS6: Subtask 1.4.5 status/progress

Subtask: 1.4.5 Recovery of high-value products from olive mill wastewater in Karmiel

Baseline technology: No material recovery so far

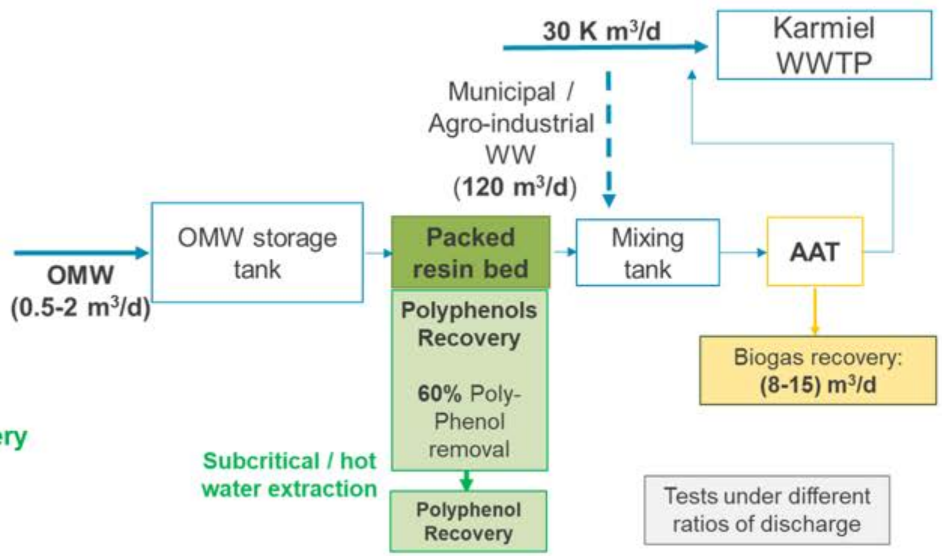
Ultimate solution to foster circular economy:
Adsorption column with packed resin bed and extraction with pressurized hot water

TRL: 5 → 7

Capacity: 0.5-2 m^3/d

Quantifiable targets: > 40% Polyphenols recovery

Status/progress:
- Detailed design completed
- Lab scale experiments almost completed



19

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CS6: Pictures of the new technologies

Subtask: 1.4.5 Recovery of high-value products from olive mill wastewater in Karmiel

Static adsorption

Lab scale – Dynamic adsorption

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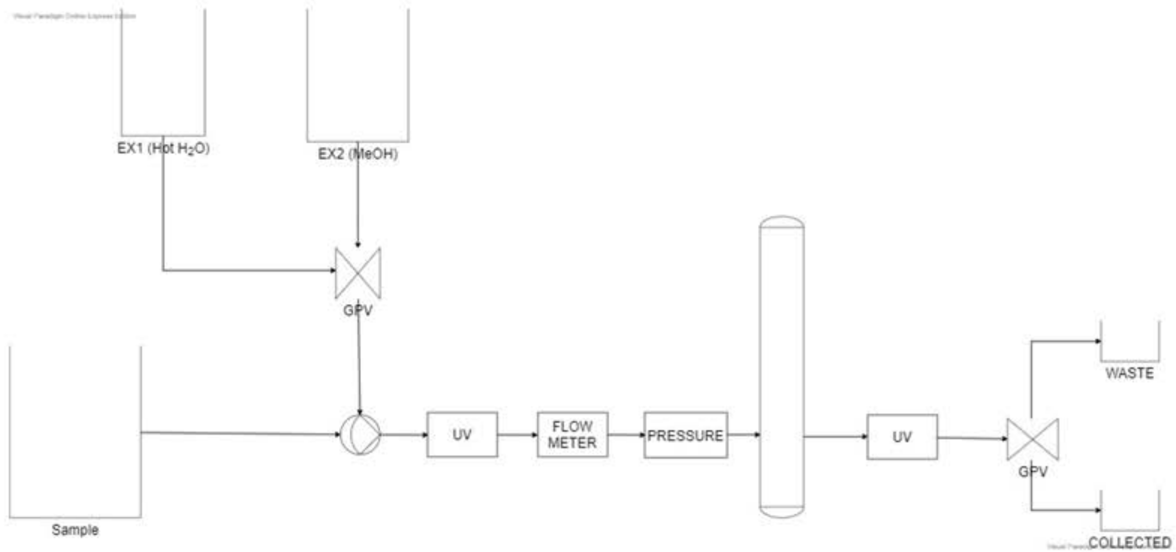
CS6: Operational procedures and methodologies

Subtask: 1.4.5 Recovery of high-value products from olive mill wastewater in Karmiel



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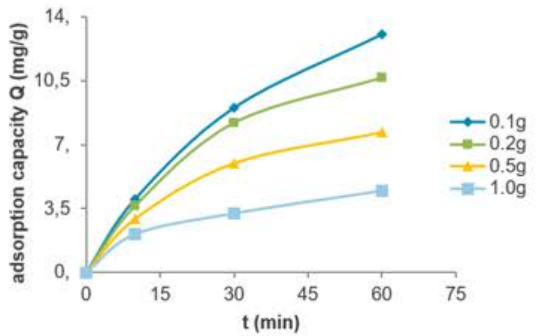
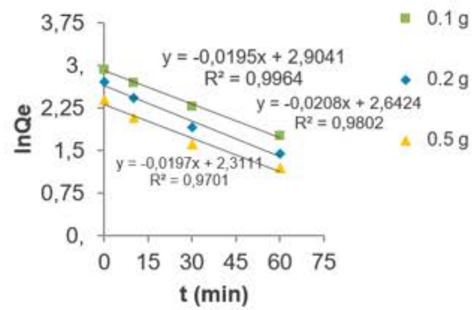
CS6: Results of the laboratory experiments

Subtask: 1.4.5 Recovery of high-value products from olive mill wastewater in Karmiel

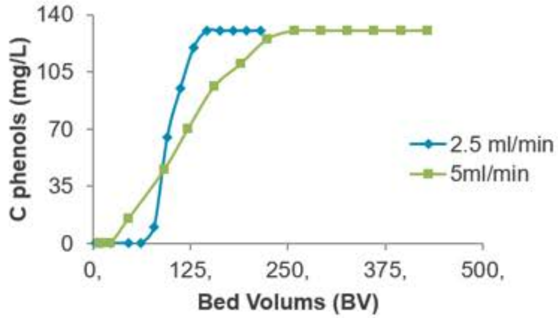
Static Adsorption





Maximum adsorptive capacity (Q): 23 g of polyphenols per kg of resin for the FPX 66 resin

Dynamic Adsorption



The breakthrough curves showed that 1.7 m^3 of wastewater can be treated per kg of resin per 10 cycles

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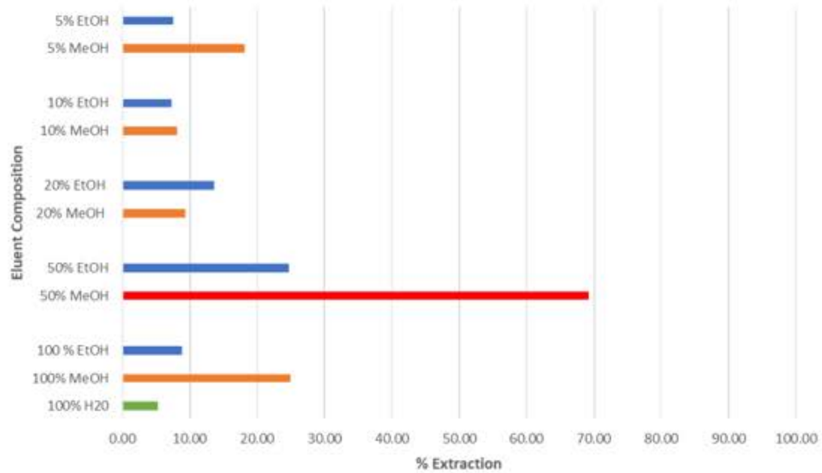
CS6: Laboratory results

Subtask: **1.4.5 Recovery of high-value products from olive mill wastewater in Karmiel**

- Static extraction experiments were performed employing hot water and organic solvents
- Water-methanol mixture (50:50 b.v.) yielded **69% polyphenols recovery**

- Currently working on dynamic extraction experiments,
- Aiming to optimise:
  - experimental conditions and
  - solvent recovery and reuse strategy



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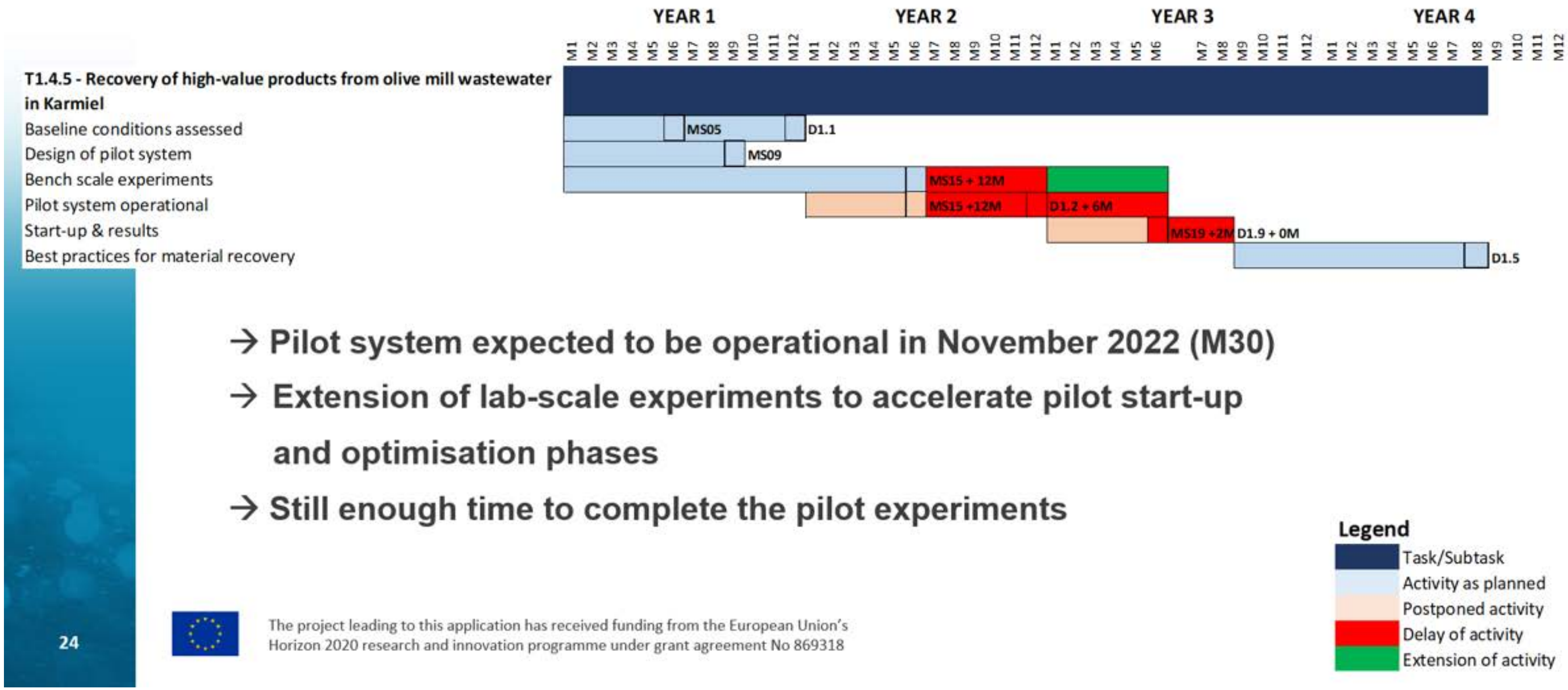
CS6: Task 1.4.5 - Timeline

Subtask: 1.4.5 Recovery of high-value products from olive mill wastewater in Karmiel



→ Pilot system expected to be operational in November 2022 (M30)

→ Extension of lab-scale experiments to accelerate pilot start-up and optimisation phases

→ Still enough time to complete the pilot experiments

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CS6 Contacts

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2.7. CS7: Tain

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
7	1.2.6	AnMBR + RO	5%	100%	100%	26
	1.3.5	AnMBR + heat recovery from its effluent		100%	100%	26
	1.4.6	Recovery of ammonia via stripping	80%			26

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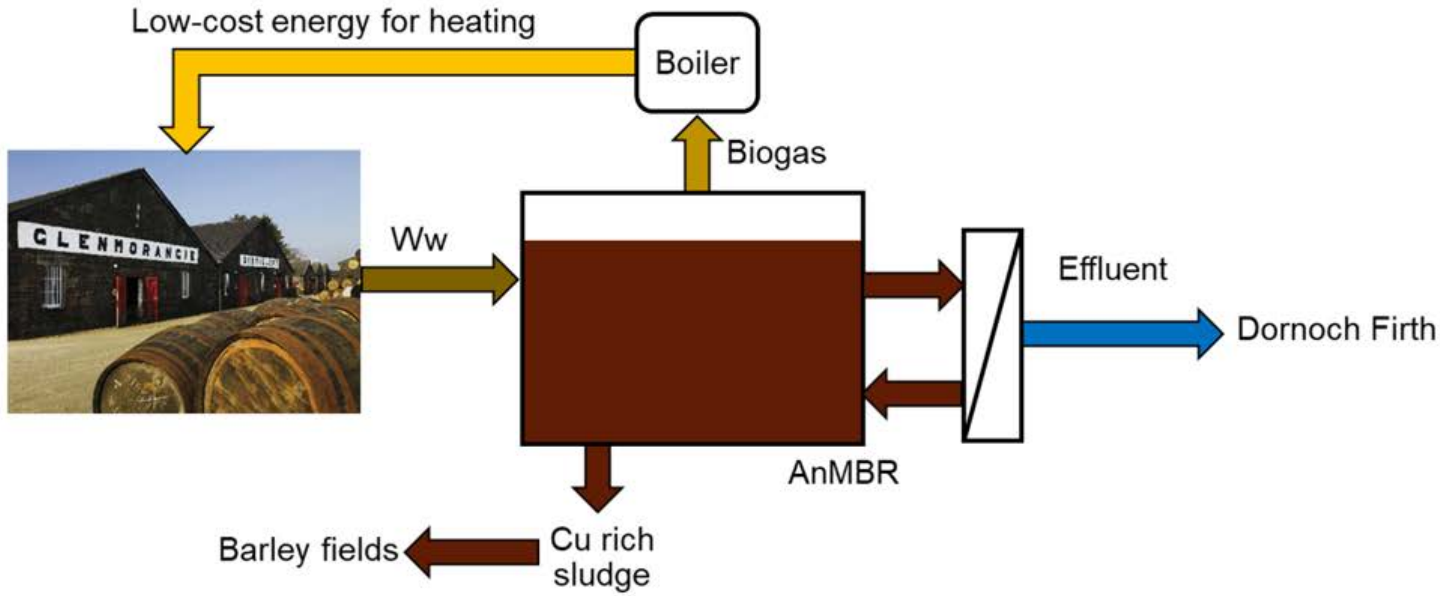
CS7: Situation before Ultimate



3

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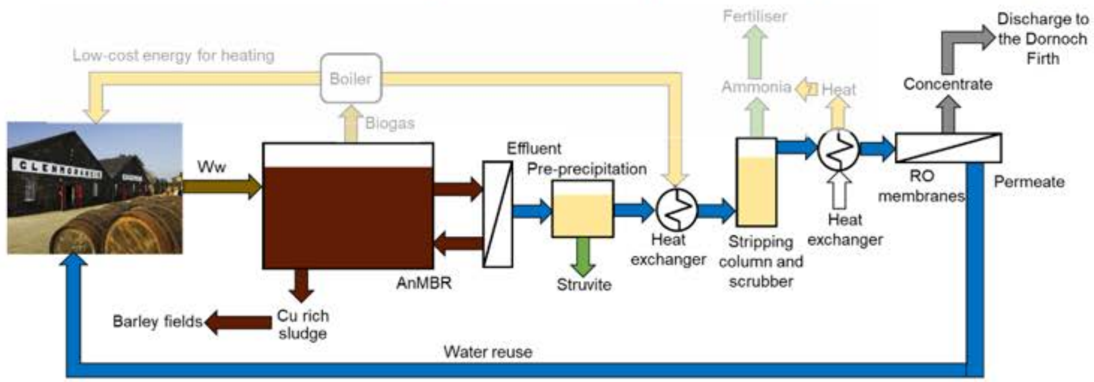
CS7: Subtask 1.2.6 status/progress

Subtask: 1.2.6 RO treatment of distillery wastewater after AnMBR for internal water reuse
Baseline technology: no water reuse so far (discharge of AnMBR effluent to Dornoch Firth)

Ultimate solution to foster circular economy: RO system for distillery wastewater (AnMBR effluent)



TRL: 5 → 7

Capacity of demo plant: 1 m³/d

Quantifiable target: At full scale, potential for the production of 58,000 m³/a for internal water reuse; >40 % reduction of freshwater through reuse of treated water

Status/progress:

- detailed design completed
- system available but needs adapting to fit latest configuration

5

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CS7: Pictures of the new technologies

Subtask: 1.2.5 RO treatment of distillery wastewater after AnMBR for internal water reuse

The RO unit is designed to achieve high quality water for reuse from the distillery wastewater after treatment through a pre-precipitation stage and ammonia stripping.

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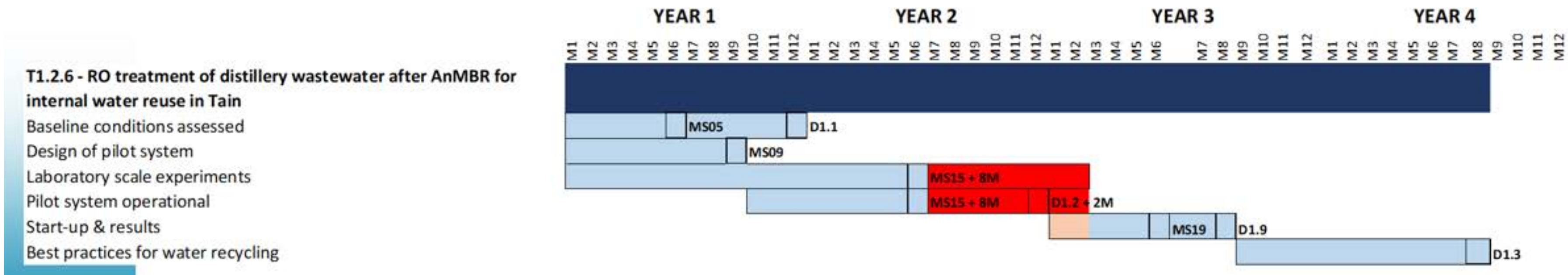
CS7: Task 1.2.6 - Timeline

Subtask: 1.2.5 RO treatment of distillery wastewater after AnMBR for internal water reuse



→ **Pilot system expected to be operational in July 2022 (M26)**

→ **Still enough time to complete the pilot experiments**

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7

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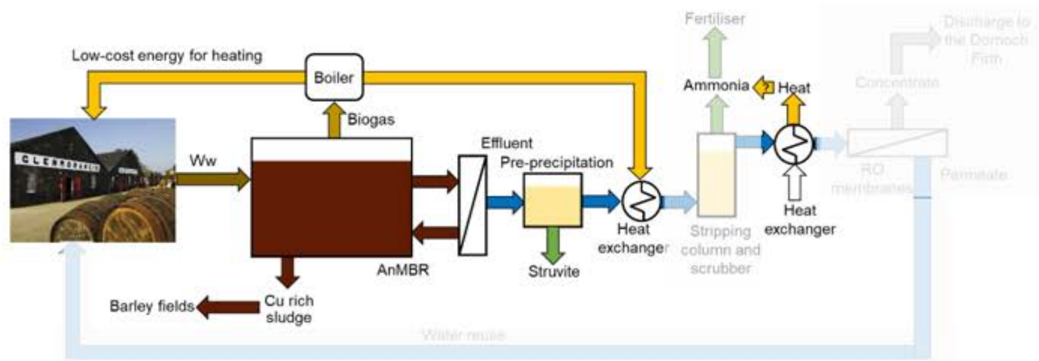
CS7: Subtask 1.3.5 status/progress

Subtask: 1.3.5 Heat recovery from treated (AnMBR) distillery wastewater

Baseline technology: Biogas production via existing AnMBR; no heat recovery before Ultimate

Ultimate solutions to foster circular economy: heat recovery from the AnMBR effluent via heat exchangers



TRL: 5 → 7

Capacity of demo plant: heat utilization will be tested in all systems at 1 m3/d for the RO and 12 m³/d for the nutrients recovery system and 14 kW of heat recovery can be expected

Quantifiable targets: At full scale, >15 % reduction of energy demand from biogas and 60 % heat recovery within stripping column unit

Status/progress:

- detailed design completed
- parts ordered

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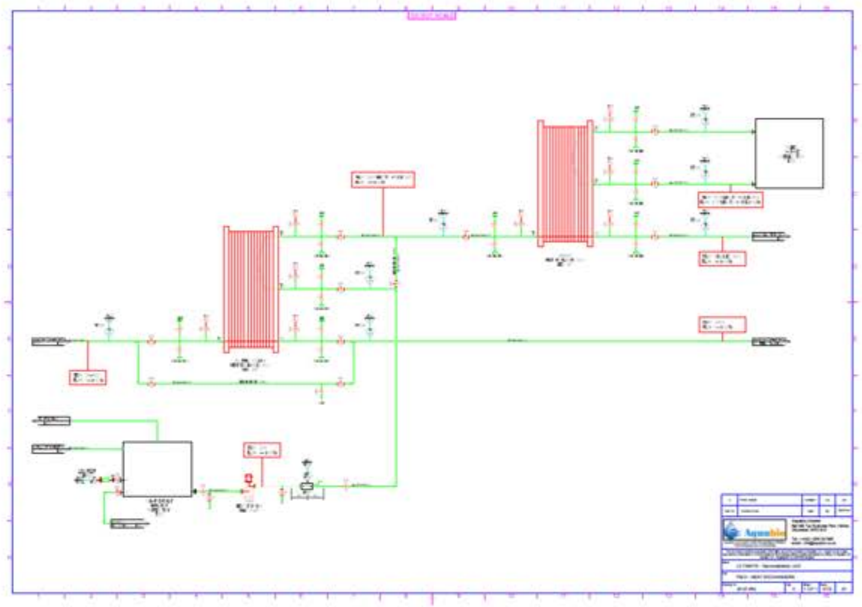
CS7: PID of the heat exchanging unit

Subtask: 1.3.5 Heat recovery from treated (AnMBR) distillery wastewater

P&ID of the heat exchange unit



The heat exchanger units are designed to maximise heat utilisation from the effluent after the ammonia stripping process.

9

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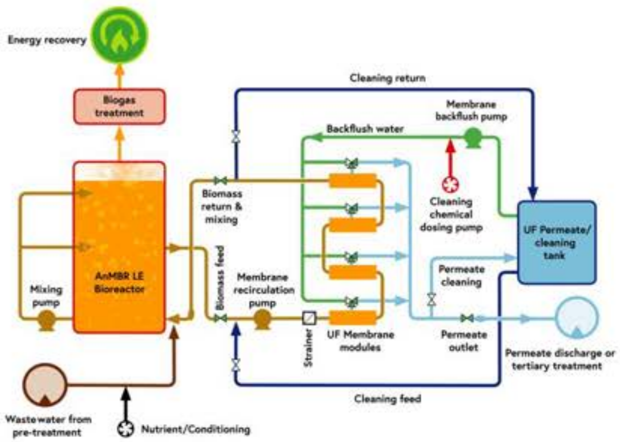
CS7: First results of the new technologies

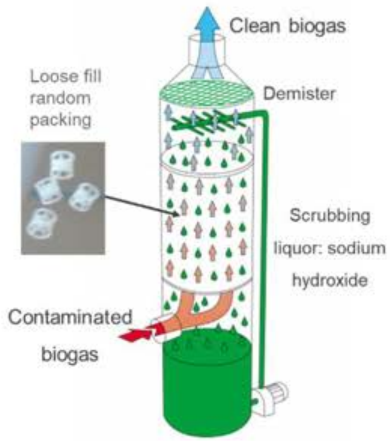
Subtask: 1.3.5 Heat recovery from treated (AnMBR) distillery wastewater

The biogas produced in the AnMBR first goes through a scrubber for H_2S removal and is then converted to steam in a boiler. The steam produced is reused to heat the stills in the distillery and contribute to reduce its dependence on fossil fuel by 15%.

Biogas Generation (Nm^3/d)	8,000
CH_4 content (%)	55-70



Packed tower scrubber for H_2S removal



https://www.forbesgroup.co.uk/environmental-technologies/packed-tower/

Biogas fired steam boiler

Maximum continuous rating (kg/hr)	2067
Design temperature (ºC)	188
Working pressure	8 barg

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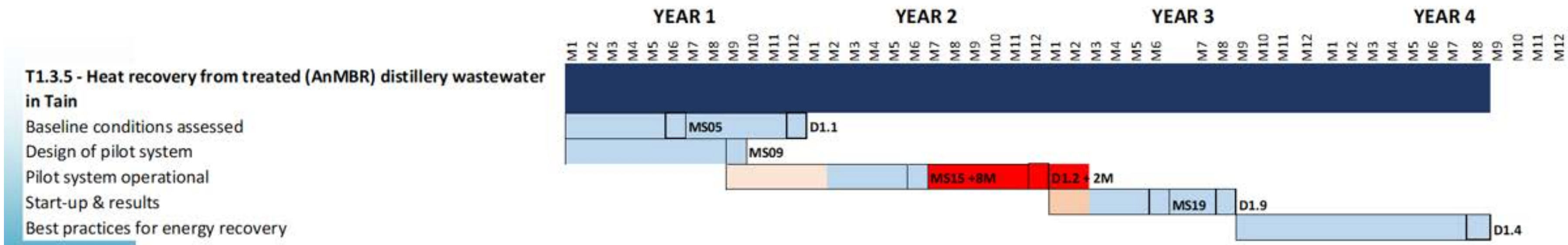
CS7: Task 1.3.5 - Timeline

Subtask: 1.3.5 Heat recovery from treated (AnMBR) distillery wastewater



→ **Heat recovery system expected to be operational in July 2022 (M26)**

→ **Still enough time to complete the pilot experiments**

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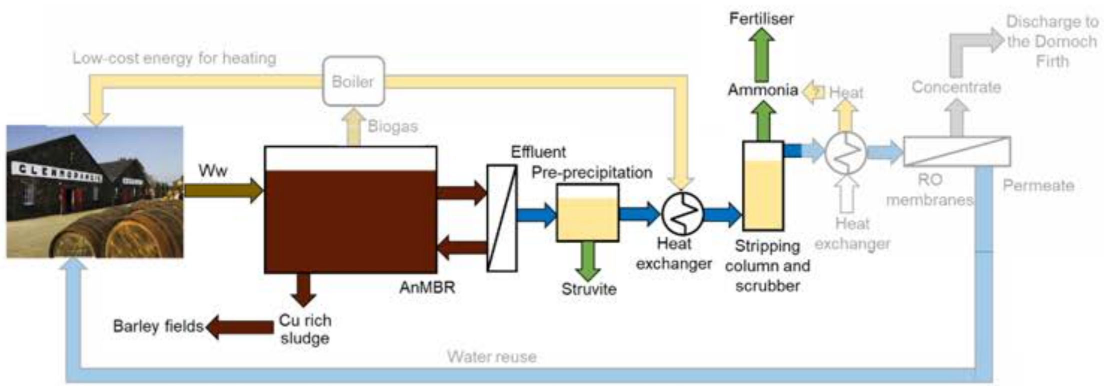
CS7: Subtask 1.4.6 status/progress

Subtask: 1.4.6 Recovery of ammonia from distillery wastewater via IEX/packed columns after AnMBR
Baseline technology: reuse of digestate on the barley fields

Ultimate solution to foster circular economy: air stripping column & scrubber; struvite precipitation



TRL: 5 → 7 (air stripping column & scrubber); **5 → 7** (struvite precipitation)

Capacity of demo plants: 12-24 m³/d

Quantifiable target: At full scale, potential for the production of 122 t struvite/a from the pre-precipitation stage and 47 t nitrogen/a from ammonia stripping, corresponding to about 80% P recovery and 80% N recovery in total

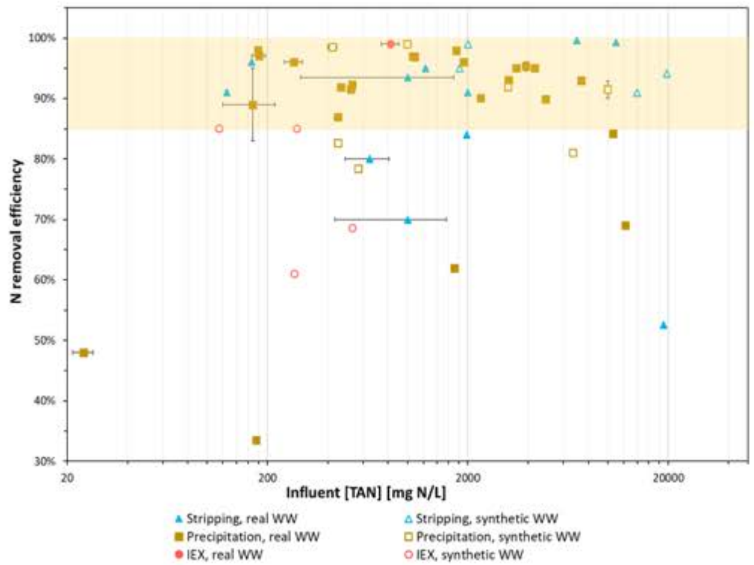
Status/progress:

- detailed design completed
- parts ordered

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS7: Results of the preliminary evaluation

Subtask: 1.4.6 Recovery of ammonia from distillery wastewater via IEX/packed columns after AnMBR



The evaluation of current knowledge and performance (see figure on the right) of ion exchange, stripping and precipitation based systems for ammonia recovery form industrial wastewaters and the measured characteristics of the anaerobically treated distillery wastewater led to the selection of a two-stage system comprising pre-precipitation (struvite) followed ammonia stripping to maximize the recovery of nutrients.

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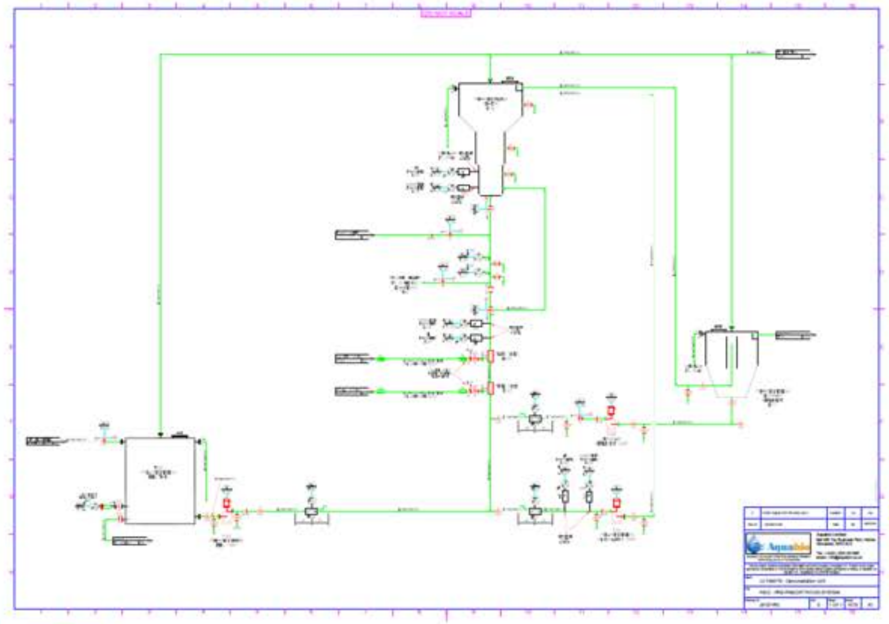
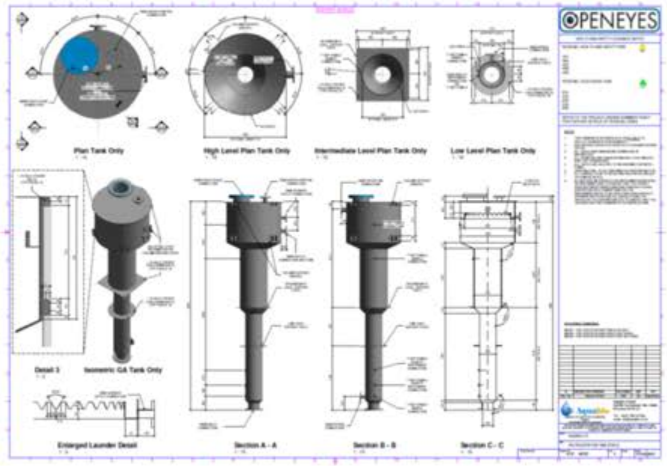
CS7: Pictures of the struvite precipitator

Subtask: 1.4.6 Recovery of ammonia from distillery wastewater after AnMBR

P&ID and drawing of the of the pre-precipitation reactor





The pre-precipitation stage will act as pre-treatment to maximize ammonia recovery in the subsequent stripping unit while also recovering P and N in the form of struvite.

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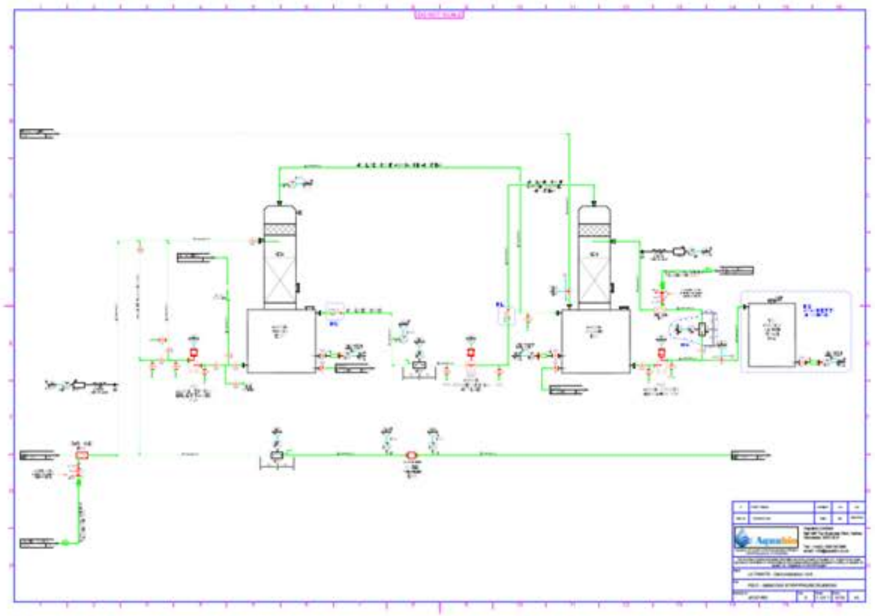
CS7: PID of the ammonia stripping unit

Subtask: 1.4.6 Recovery of ammonia from distillery wastewater after AnMBR

P&ID of the ammonia stripping unit



The stripping unit is designed to maximize the recovery of ammonia from the anaerobically treated distillery wastewater in the form of either an ammonia solution or ammonium sulphate.

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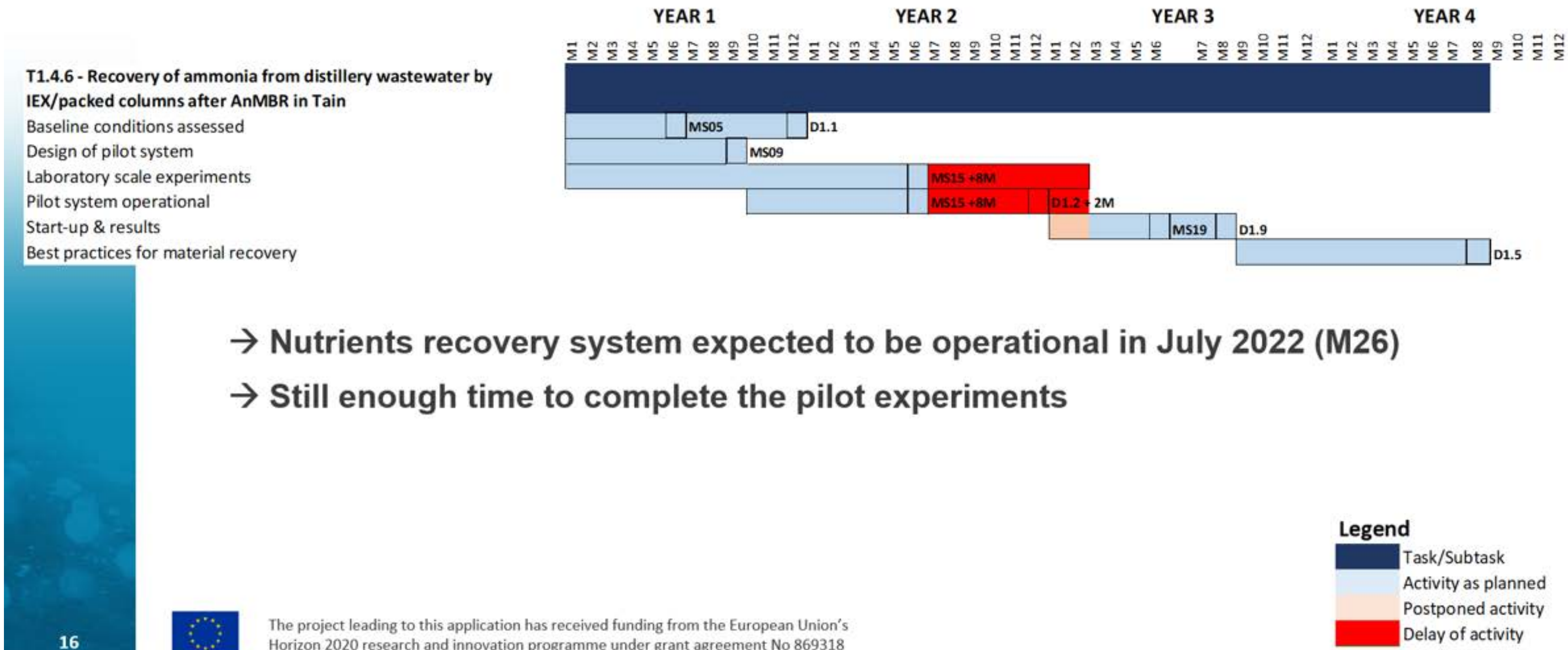
CS7: Task 1.4.6 - Timeline

Subtask: 1.4.6 Recovery of ammonia from distillery wastewater after AnMBR



→ **Nutrients recovery system expected to be operational in July 2022 (M26)**

→ **Still enough time to complete the pilot experiments**

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WATER SMART INDUSTRIAL SYMBIOSIS

CS7 Contacts

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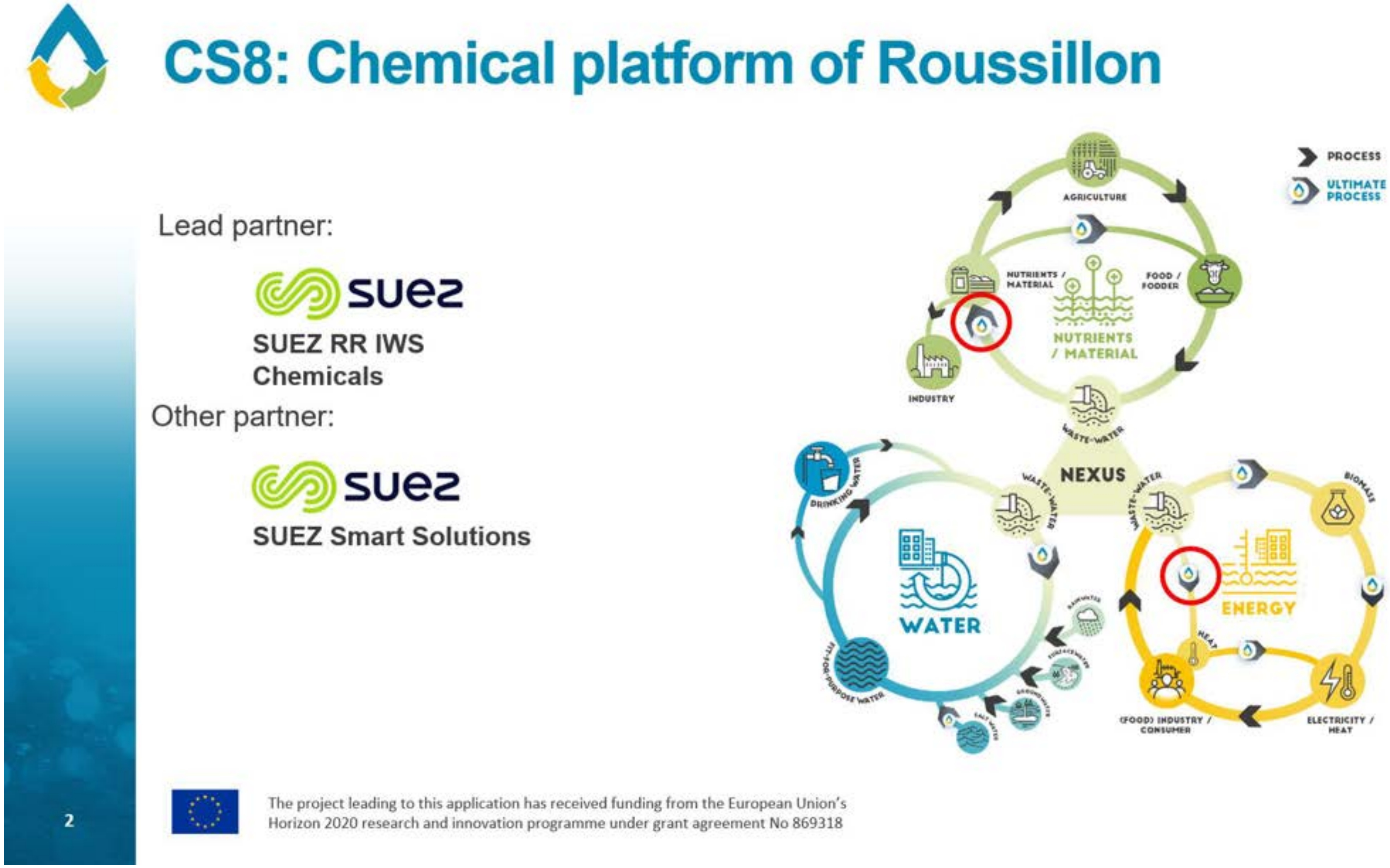
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

2.8. CS8: Chemical platform of Roussillon

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
8	1.3.6	Feasibility study: heat recovery	No pilot plant --> excluded from D1.2			
	1.4.7	Recovery of sulfur: pilot demonstration	75%	10%		28



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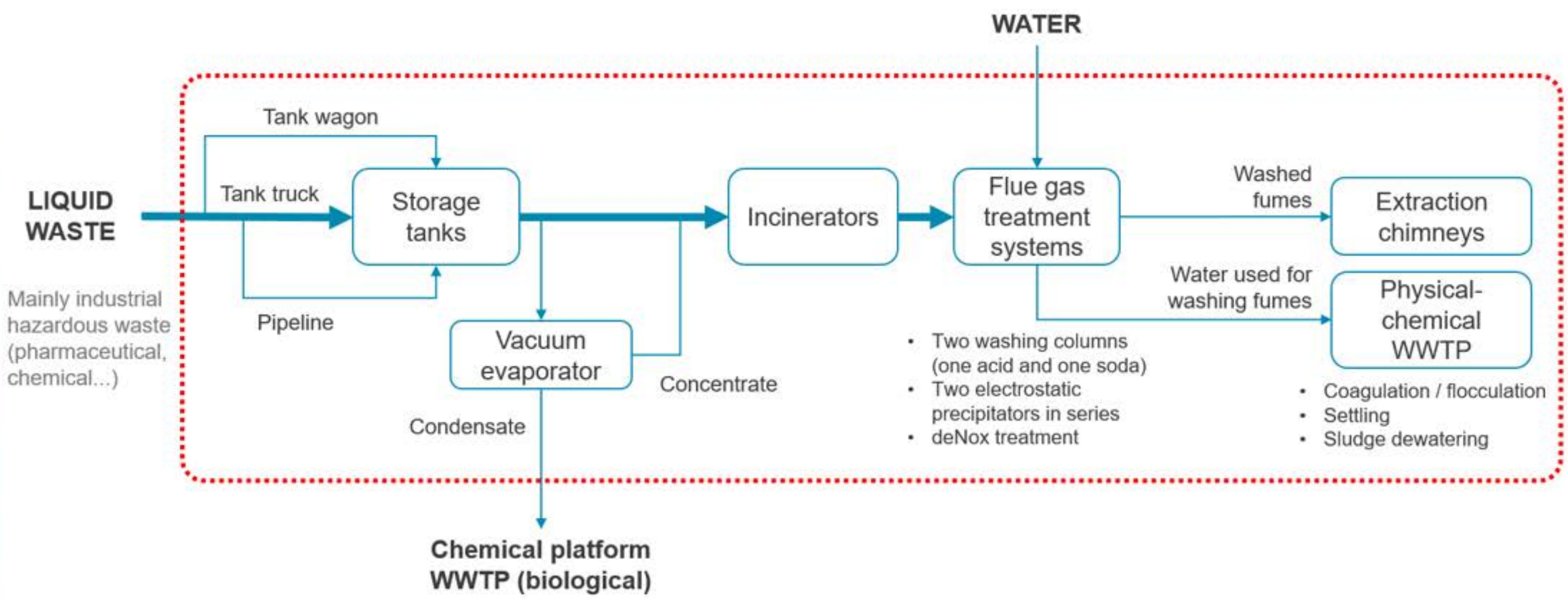
CS8: Situation before Ultimate



3

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CS8: Subtask 1.4.7 status/progress

Subtask: **1.4.7 Recovery of sulphur at the chemical platform of Roussillon**

Baseline technology: **no sulphur recovery so far**

Ultimate solution to foster circular economy:

- **Sulphur recovery from flue gas:** condensation, dust cleaning and scrubbing
- **Sulphur recovery from effluent WWTP:** electrolytic oxidation or natural flocculating agents or chemical precipitation of sulphates

TRL: **4 → 6** (Sulphur recovery)

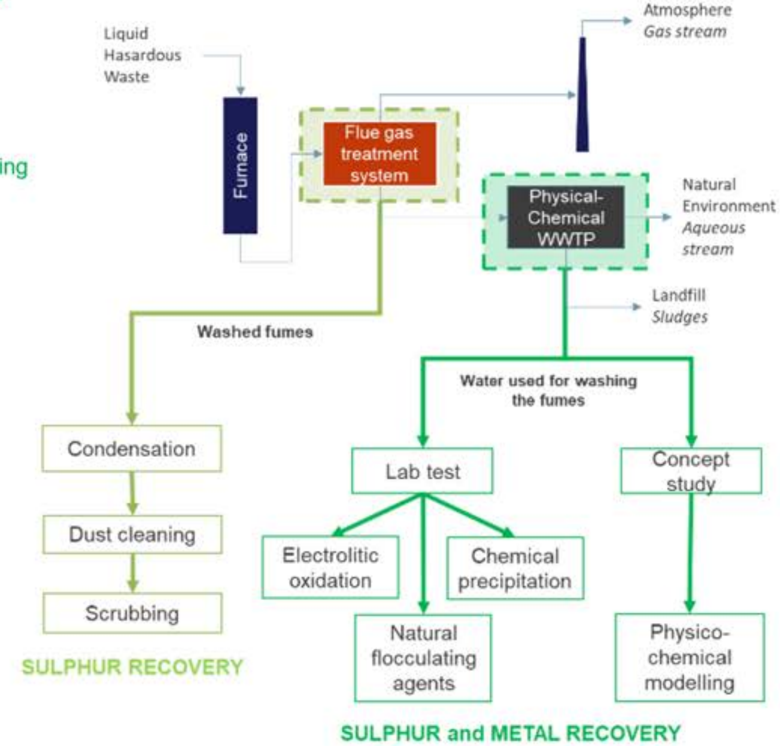
Capacity:
Sulphur from flue gas: 25 000 Nm^3 flue gas/h at 0-1% SO_2 depending on the feed waste ;
Sulphur from effluent WWTP: 1 100 m^3/d corresponding to about 15 t/d of sulphates

Quantifiable target:

- **Sulphur from flue gas:** 80% sulphur recovery;
- **Sulphur from effluent WWTP**: 80% sulphur recovery

Status/progress:

- **Sulphur from flue gas:** lab pilot plant under construction; lab experiments ongoing
- **Sulphur from effluent WWTP:** preparation of lab tests



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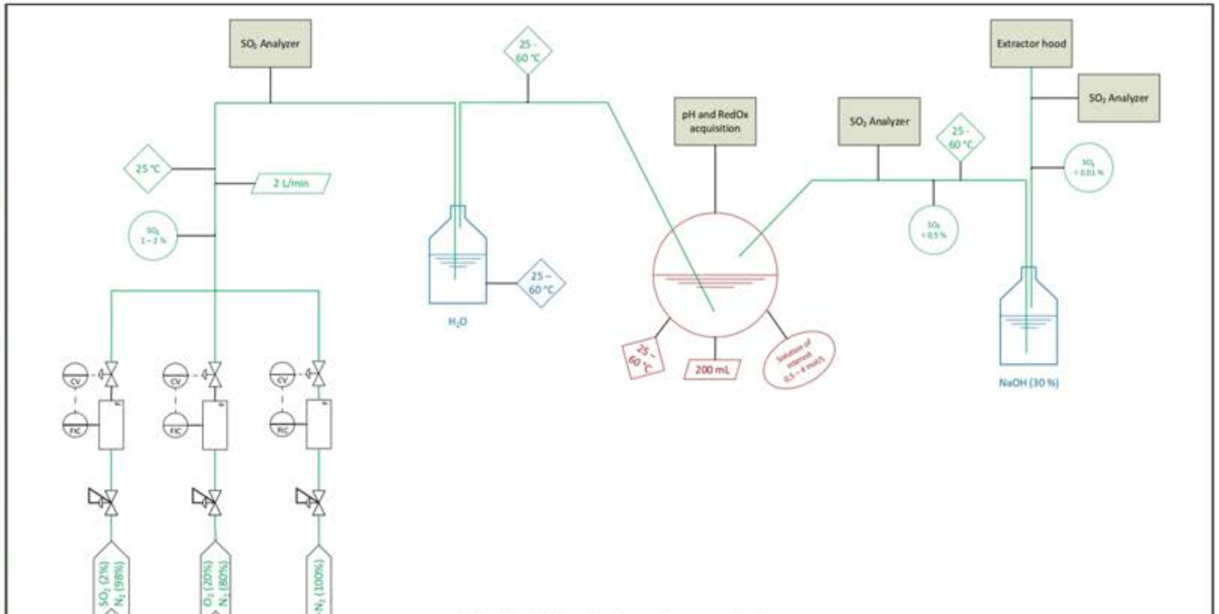
CS8: The laboratory pilot

Subtask: 1.4.7 Recovery of sulphur at the chemical platform of Roussillon



PFD of the laboratory pilot

Sizing :

Creation of a laboratory pilot able to study the impact of certain operating characteristics on the absorption of SO_2.

→ Use of an experimental design to effectively analyze these impacts.

Objective :

Determine precisely the ideal configuration to absorb SO_2 and concentrate the solution of interest.

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CS8: The laboratory pilot

Subtask: 1.4.7 Recovery of sulphur at the chemical platform of Roussillon

Gas mixture :

Allows to study :

→ The SO_2 level (0,1 to 1,5 %) ;

→ The O_2/SO_2 ratio (5 to 100).

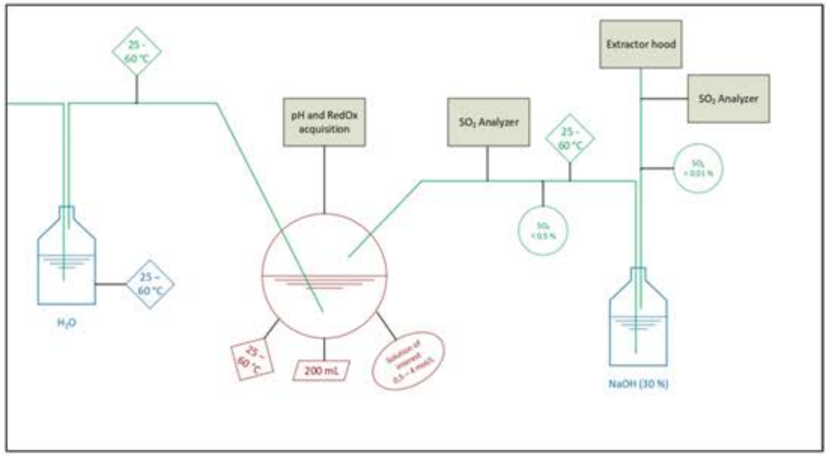
Analysis :

→ SO_2 analyzer ;

→ Test kits (liquid phase characterization).

→ pH sensor ;

→ RedOx potential sensor.

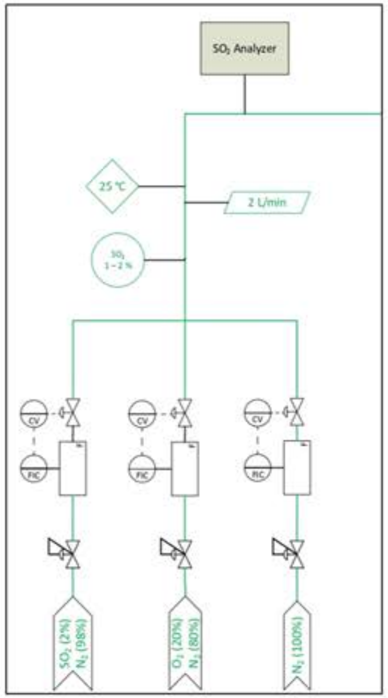


PFD of the laboratory pilot : Focus on the reactor

Other parameters :

→ Temperature ;

→ Initial composition of the liquid phase.



PFD of the laboratory pilot : Focus on the gas mixture

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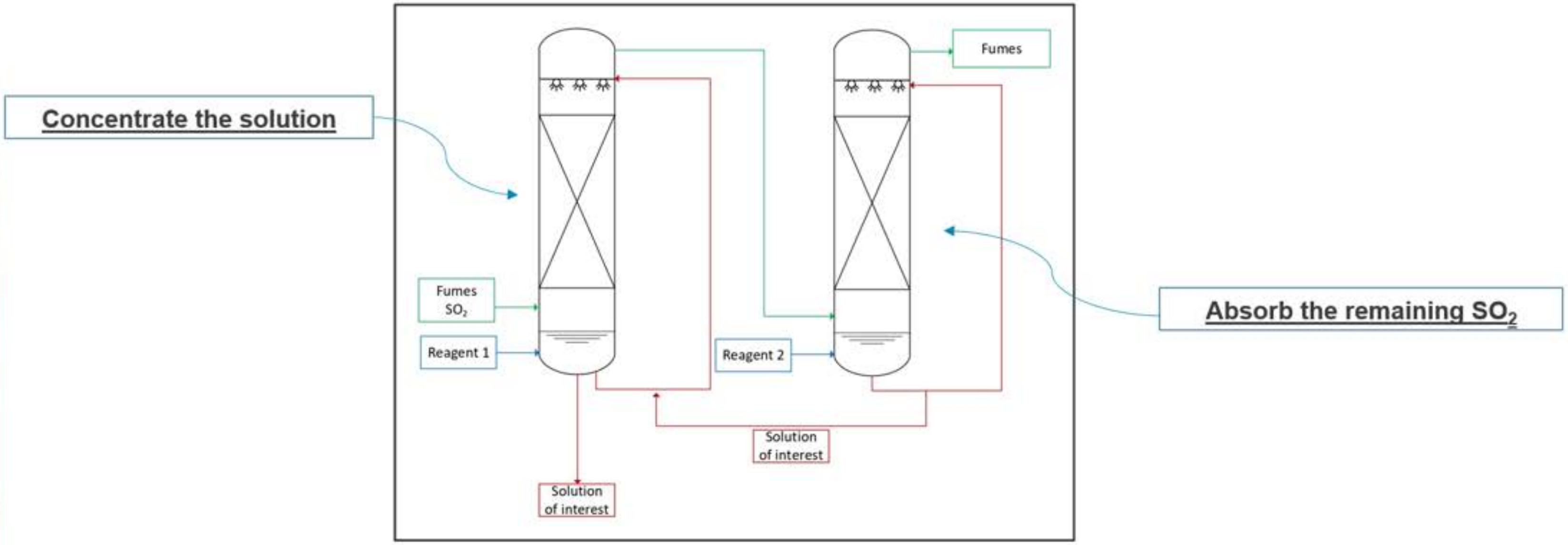
CS8: The industrial pilot

Subtask: 1.4.7 Recovery of sulphur at the chemical platform of Roussillon



Principle of the industrial pilot

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CS8: The industrial pilot

Subtask: 1.4.7 Recovery of sulphur at the chemical platform of Roussillon

Sizing :

→ Column sizing ;

→ Realization of the PFD and the mass balance ;

→ Realization of the PID.

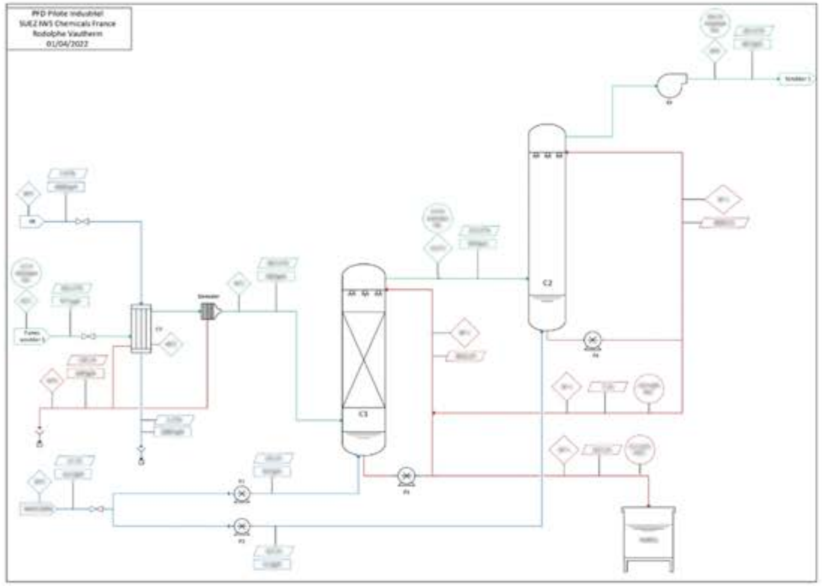
Pilot's specifications are already realized and contact with suppliers is underway.

Addition of a condenser : Required if we want to concentrate the product.

→ By temperature decrease in the columns, water contained in the fumes will condense and significantly dilute the solution.

Two different columns : A packed and a spray column.

→ Interesting to compare because in this case, they seem to have equivalent performances.



PFD of the industrial pilot

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CS8: Status & Outlook

Subtask: 1.4.7 Recovery of sulphur at the chemical platform of Roussillon

Done :

→ Validation of analytical techniques ;
→ Purchase of a SO_2 analyzer ;
→ Sizing of the laboratory pilot ;
→ Sizing of the industrial pilot and drafting of the specifications.

To do :

→ Build the laboratory pilot after receipt of components ;
→ Continue the experiments in the laboratory ;
→ Build the industrial pilot and connect it to the site.

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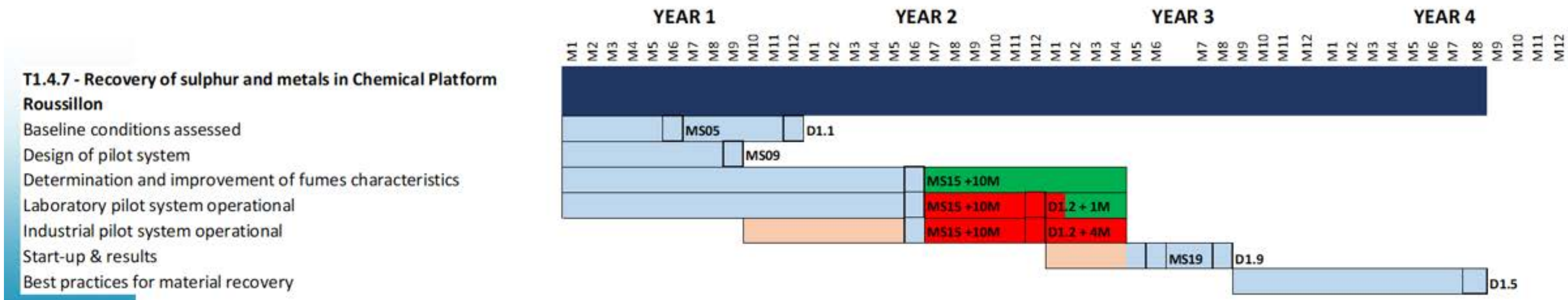
CS8: Task 1.4.7 - Timeline

Subtask: 1.4.7 Recovery of sulphur at the chemical platform of Roussillon



→ Laboratory pilot system expected to be operational in June 2022 (M25)

→ Industrial pilot system expected to be operational in November 2022 (M30)

→ Extension of lab-scale experiments to accelerate pilot start-up and optimisation phases

→ Still enough time to complete the pilot experiments

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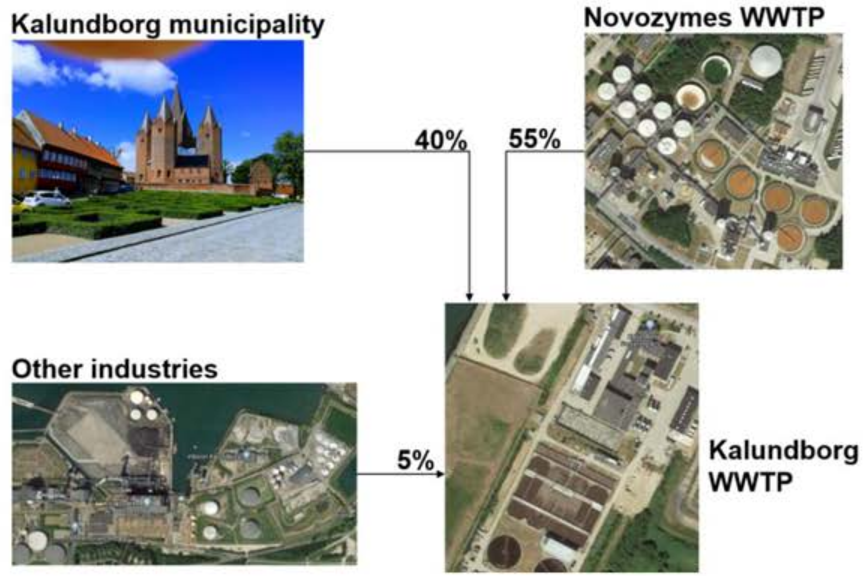
2.9. CS9: Kalundborg

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
9	1.2.7	Novel UF membrane		100%	100%	24
	1.3.7	Joint control system	No pilot plant --> excluded from D1.2			
	1.4.8	Concept study: high added value product recovery	No pilot plant --> excluded from D1.2			

CS9: Situation before Ultimate

- No water reclamation from WWTP effluent
- Each WWTP has its separate control system
- No high added value product recovery from wastewater so far



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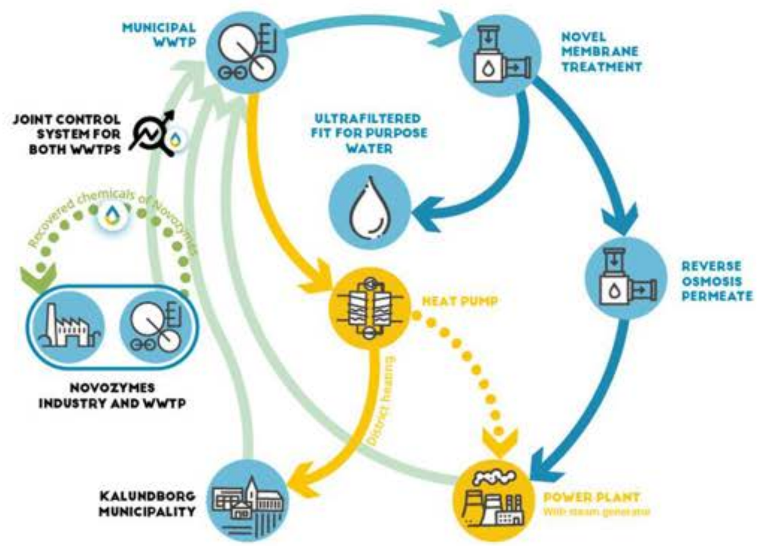
CS9: Project objectives in Kalundborg:

- **Production of fit-for-purpose water** using a novel membrane pre-treatment for wastewater with high non-degradable organic matter
- **Energy efficiency increase** through a synergetic operation of two WWTPs and concept study for heat recovery
- Concept study for **nutrient and/or high-value product recovery**



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CS9: Pilot plant is operational → D1.2

Subtask: 1.2.7 Novel membrane treatment for biotech or biotech and municipal WWTP effluent for water reuse

Baseline technology: no water reuse so far (discharge to the recipient)

Ultimate solution to foster circular economy: novel tight ultrafiltration & reverse osmosis system

TRL: 5 → 7
Capacity: 10 m³/h

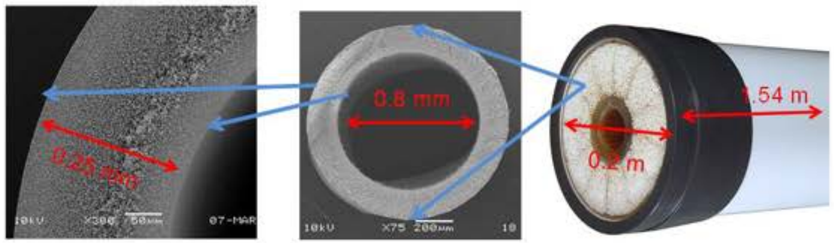
Quantifiable targets:

- Fit-for-purpose water production from pilot plant > 70,000 m³/a
- Ambition beyond the project: >40 % reduction of surface water through reuse of treated water

Status/progress:

- 2 pilot plants have been constructed
- Operational since June 2021

Novel tight ultrafiltration membrane
Molecular weight cut off: 4 kDa



Fibre wall | Fibre | Module head

5

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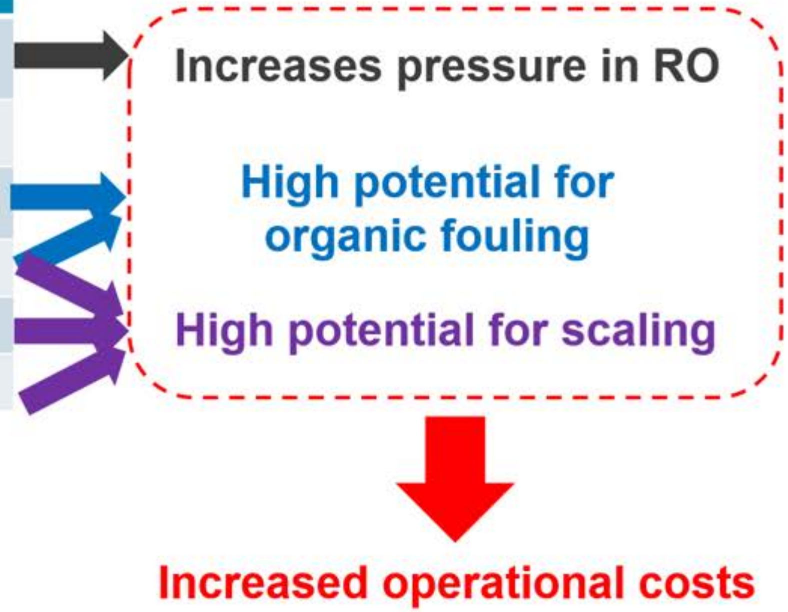
CS9: Specific challenges at the municipal WWTP

Subtask: 1.2.7 Novel membrane treatment for biotech or biotech and municipal WWTP effluent for water reuse

Parameter	Unit	Content
Electrical conductivity	µS/cm	2800-8200
Total dissolved solids	mg/L	3500-4200
TOC / COD	mg/L	20-60 / 50-190
Calcium	mg/L	98-130
Hydrogen carbonate	mg/L	1000-1100
Sulphate	mg/L	440-510



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CS9: Operational procedures and methodologies

Subtask: 1.2.7 Novel membrane treatment for biotech or biotech and municipal WWTP effluent for water reuse

Fouling prevention:

- Does the novel ultra tight membrane prevent better the RO from fouling than a conventional UF?

  → Pilot A (conventional membrane) and pilot B (novel membrane) are operated in parallel in order to compare their performance in terms of fouling prevention

Production of fit-for-purpose water:

- Can we produce fit-for-purpose water for cooling towers and/or boilers?
- Which water quality is reached after UF and for which reuse purpose can the water be used (truck or street cleaning)?

  → Investigation of water quality after each treatment step

→ Both objectives will be investigated in the frame of three scenarios (next slide)

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CS9: Three different water qualities as inflow to the pilot

I. Scenario

Inflow: Effluent from municipal WWTP

Treatment train: Ultrafiltration (UF) & reverse osmosis (RO)

II. Scenario (lower fouling potential)

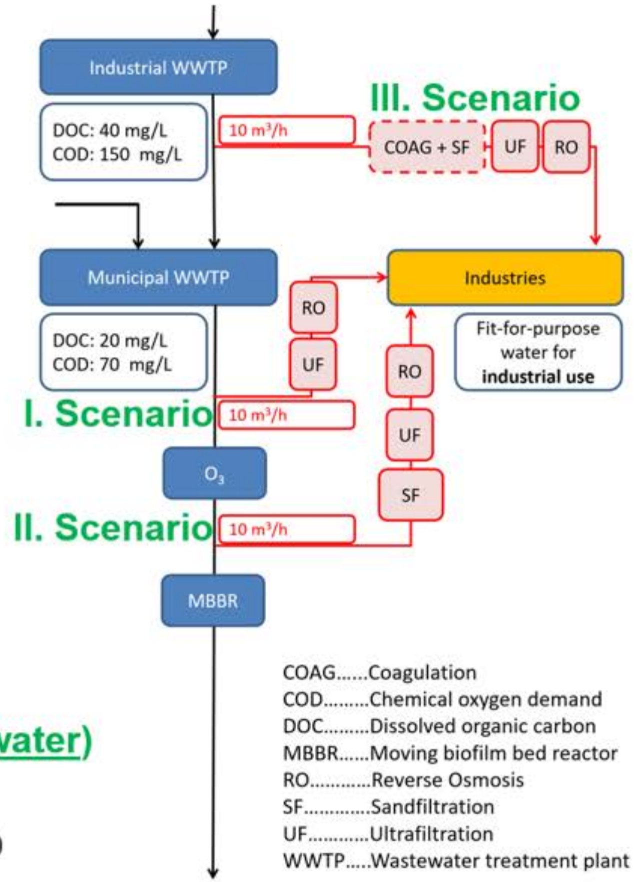
Inflow: Effluent from ozonation

Treatment train: Sandfilter (SF), UF & RO

III. Scenario (higher fouling potential & process water)

Inflow: Effluent from industrial WWTP

Treatment train: Coagulation (COAG), SF, UF & RO



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CS9: Pictures of the pilot plants

Subtask: 1.2.7 Novel membrane treatment for biotech or biotech and municipal WWTP effluent for water reuse

Pilot A: conventional UF & RO

Pilot B: novel ultra tight UF membrane & RO

9

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CS9: Pictures of the pilot plants

Subtask: 1.2.7 Novel membrane treatment for biotech or biotech and municipal WWTP effluent for water reuse

Pilot A (conventional UF membrane)

Reverse osmosis membranes

Pilot B (novel UF membrane)

10

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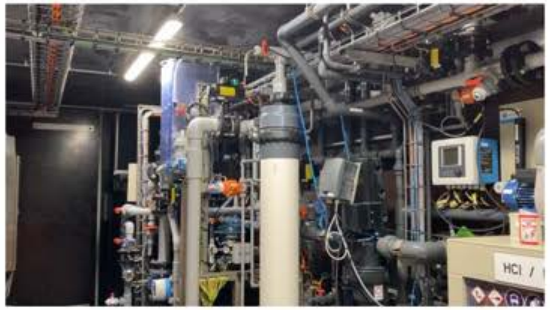
CS9: Videos of the pilot plants in operation

Subtask: 1.2.7 Novel membrane treatment for biotech or biotech and municipal WWTP effluent for water reuse

Pilot A (conventional UF membrane)

Reverse osmosis membranes

Pilot B (novel UF membrane)



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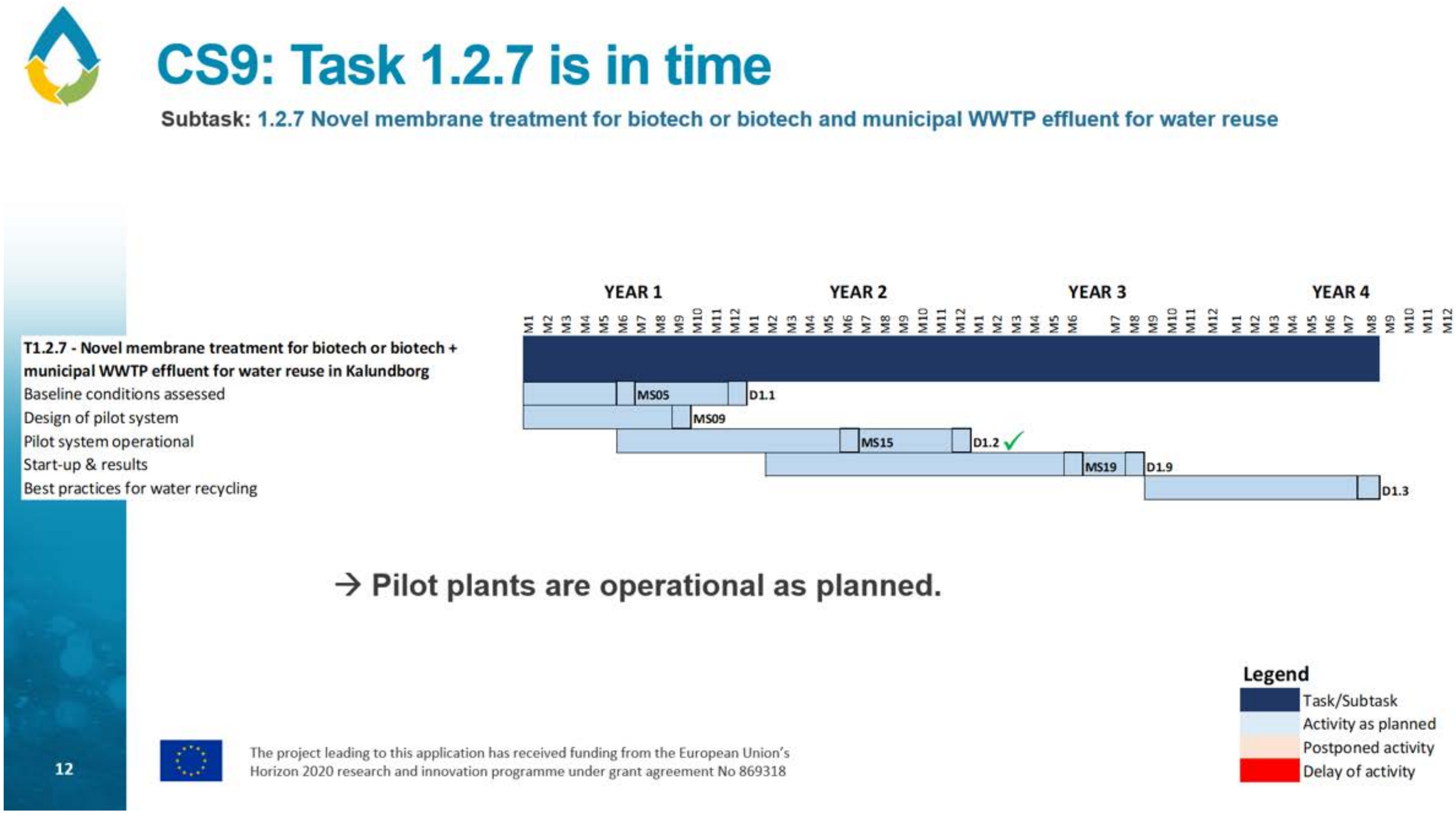

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3. Summary and conclusion

ULTIMATE aims to showcase circular economy solutions at nine case studies distributed across Europe and Israel for the treatment of industrial wastewater in order to recover water, material and energy. In this frame, 15 laboratory and preparatory experiments and investigations of existing systems are conducted to test the ULTIMATE approaches and based on them, 21 pilot plants are developed and will be demonstrated at the case studies.

Deliverable D1.2 is a demonstrator type deliverable and shows, that the ULTIMATE pilot plants are operational. To document the status for each case study, a presentation containing pictures and/or videos of the operational pilot plant is accessible on the ULTIMATE webpage (https://ultimatewater.eu/demonstration-cases/). This document accompanies the presentations which are meant to be the main evidence for D1.2 and shows the progress until M24.

Table 3 provides an overview about the progress of the pilot systems and of the laboratory experiments. Eight of the WSISs conduct laboratory experiments, before they implement their pilot plants. In total, 15 different laboratory experiments and/or investigations of already existing facilities are accomplished to better understand the circumstances of the real environment and to learn more about the type of technology before it is up-scaled from laboratory to pilot scale. Seven of the 15 investigations are already completed and seven are close to be completed with a progress between 75% and 90%.

Until M24, five pilot plants or (parts of) treatment trains were operational. Three of them are related to water recovery at the case studies in Nafplio (CS4), Lleida (CS5) and Kalundborg (CS9). One of them is related to material recovery in Lleida (CS5) and the last one is related to energy recovery in Karmiel (CS6).

Until M27, ten additional plants are expected to be operational. Most of them are quite close to be constructed with a progress between 70% and 100% such as the material recovery unit in Rosignano (CS3), final parts of the water recovery treatment train in Lleida (CS5), two energy recovery units in Lleida (CS5) and one energy recovery unit in Shafdan (CS6). Even though the progress is only at 25% in Tarragona (CS1), the case study leader expects the two pilot plants for water recovery to be operational until M27 as for the pilot plants in Tain (CS7) dealing with water, nutrient and energy recovery and reuse.

Until M30, the last six pilot plants shall be operational according to the case study leaders. One of the six pilot plants recovers water, one recovers energy and the other four recovery different materials. Especially for those six pilot plants, the contingency plan is to extend and intensify the laboratory and preparatory experiments to gain more important data and experience in depth that suggest to accelerate and to shorten the start-up and optimisation phase of the pilot plants. Even though all case study leaders

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still expect to complete their pilot test within the project life time of 48 months, time is becoming a critical factor as sufficient time is required to gain experience from the pilots and translate this into best practices for WSIS implementation.

Table 3 Overview about the progress regarding the construction and the operation of the pilot plants

Overview			D1.2: Operational demo cases in M24			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Expected to be operational [M]
1	1.2.1	RO + MD; ammonia removal via zeolites	100%	25%		25
2	1.2.2	Reclamation of greenhouse drain water using electrodialysis	75%	25%		28
	1.3.1	HT-ATES	No pilot plant --> excluded from D1.2			
	1.4.1	Recovery of nutrients: test beddings & demo greenhouse	75%	25%		28
3	1.2.3	Control system to aviod high chlorine concentrations	No pilot plant --> excluded from D1.2			
	1.4.2	Use of byproducts: pilot scale adsorption system	85%	80%		25
4	1.2.4	Reuse of fruit processing WW: filtration, AOP, SBP	100%	100%	100%	24
	1.4.3	Recovery of antioxidants: adsorption/extraction	100%	85%		30
5	1.2.5	(NF + RO) + (AOP + UV)	100%	100% / 75%	100%	20; 25
	1.3.2	AnMBR	100%	100%	25%	25
		ELSAR	100%			30
		SOFC		100%	50%	26
	1.4.4	Concept study: Recovery nutrients from digestate; fertigation stategies	No pilot plant --> excluded from D1.2			
		Solar-driven hydrothermal carbonisation demo plant	100%	100%	100%	24
6	1.3.3	AAT Karmiel		100%	100%	24
	1.3.4	AAT + membrane filtration incl. PAC Shafdan	90%	90%		25
	1.4.5	Recovery polyphenols (pilot system: adsorption column)	90%			30
7	1.2.6	AnMBR + RO	5%	100%	100%	26
	1.3.5	AnMBR + heat recovery from its effluent		100%	100%	26
	1.4.6	Recovery of ammonia via stripping	80%			26
8	1.3.6	Feasibility study: heat recovery	No pilot plant --> excluded from D1.2			
	1.4.7	Recovery of sulfur: pilot demonstration	75%	10%		28
9	1.2.7	Novel UF membrane		100%	100%	24
	1.3.7	Joint control system	No pilot plant --> excluded from D1.2			
	1.4.8	Concept study: high added value product recovery	No pilot plant --> excluded from D1.2			

Until all pilot plants will be operational, a very close monitoring of the case studies will be done by the WP1 management team with the case study leaders and the risk officer via regularly meetings. In addition, the presentations referring to D1.2 will be updated every three months until every pilot plant will be operational.

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