ULTIMATE
WATER SMART INDUSTRIAL SYMBIOSIS

Accompanying document to

Deliverable 1.2

Operational demo cases

Author(s): A. Kleyböcker, C. Bruni, F. Fantone, A. Naves Arnaldos, J. van den Broeke, T. Guleria, M. Touloupi, D. Iossifidis, A. Gimenez Lorang, I. Sabbah, K. Farah, M. Pidou, A. Reguer, L. Vredenbregt, P. Thisgaard, U. Miehe

Date: 09/08/2023

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

Technical References

Project Acronym	ULTIMATE
Project Title	ULTIMATE: indUstry water-utiLiTy symbIosis for a sMarter wATer society
Project Coordinator	Gerard van den Berg KWR
Project Duration	01.06.2020 – 31.10.2024 (53 months)

Deliverable No.	1.2
Dissemination level [1]	PU
Work Package	1
Task	1.2.1, 1.2.2, 1.2.4-1.2.9, 1.3.2-1.3.5, 1.4.1-1.4.3, 1.4.5-1.4.7
Lead beneficiary	KWB
Contributing beneficiary(ies)	UNIVPM, EUT, KWR, GTG TECH, AQUALIA, GSR, UCRAN, SUEZ RR, X-FLOW, KALUND
Author(s)	A. Kleyböcker, C. Bruni, F. Fantone, A. Naves Arnaldos, J. van den Broeke, T. Guleria, M. Touloupi, D. Iossifidis, A. Gimenez Lorang, I. Sabbah, K. Farah, M. Pidou, A. Reguer, L. Vredenbregt, P. Thisgaard, U. Miehe
Quality Assurance	J. van den Broeke, Q. Plana Puig, A. Naves Arnaldos, G. van den Berg
Due date of deliverable	31.05.2022
Actual submission date	27.05.2022; updated and re-submitted on 09.08.2023

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

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

Document history

V	Date	Author(s) /Reviewer(s) (Beneficiary)	Description
0.1	25.04.2022	A. Kleyböcker, C. Bruni, A. Naves Arnaldos	First version sent to internal reviewer
0.2	02.05.2022	J. van den Broeke	Feedback internal review
0.3	09.05.2022	A. Kleyböcker, C. Bruni, A. Naves Arnaldos	Feedback addressed and sent to external reviewer
0.4	18.05.2022	Queralt Plana Puig	Feedback external review
0.5	23.05.2022	A. Kleyböcker, C. Bruni, A. Naves Arnaldos	Feedback addressed and sent to QA (Andrea/Gerard)
1	27.05.2022	A. Kleyböcker, C. Bruni, A. Naves Arnaldos	Feedback addressed and submit to EC
2	09.08.2023	A. Kleyböcker et al.	Updated D1.2 with all operational pilots until June 2023

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

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 nine WSISs. They develop and demonstrate 24 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 M37.

Prior to the pilot plant implementation, eight WSISs conducted laboratory experiments. In total, 17 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. Eleven of the 17 investigations are already completed and four 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 to material recovery in Lleida (CS5) and the last one to energy recovery in Karmiel (CS6).
Until M27, five additional plants were operational. Two of them refer to water recovery in Lleida (CS5) and Tain (CS7), one to material reuse in Rosignano (CS3) and two to energy recovery and reuse in Shafdan (CS6) and Tain (CS7).

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

Until M30, six additional pilots were put into operation. Two relate to water recovery and are located in Tarragona (CS1). One was implemented in Nieuw Prinsenland (CS2) and refers to water recovery and material recovery. The other three pilots focus on material recovery and were put into operation in Napflio (CS4), Tain (CS7) and at the Chemical Platform of Roussillon (CS8).
Since M33, four additional pilots are operational in Lleida (CS5) and in Karmiel (CS6) referring to energy recovery and material recovery, respectively.
In the course of the project, three pilots had been included in the description of work in addition. Due to their later inclusion, they have a different time planning and hence, two of them are not operational yet. They will be located in Rosignano (CS3) and are expected to be operational in September 2023 and in January 2024. Furthermore, the full-scale electrostimulated anaerobic reactor (ELSAR, CS5) has also another time planning and is expected be operational in September 2023 as the industrial pilot plant of CS8 is at the Chemical Platform of Roussillon.
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 further updated every three months until every pilot plant will be operational. Those results will then be reported in the best practice guidelines (D1.3, D1.4 and D1.5).

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 (D2.2 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.

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

Disclaimer

This publication reflects only the author’s views and the European Union is not liable for any use that may be made of the information contained therein.

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

Table of Contents

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

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
NF	Nanofiltration
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

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

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 24 pilot, full-scale and industrial-scale plants, which recover water, materials and/or energy (Table 1).
Hereby, eight, six and nine pilot plants refer to water recovery, energy recovery and material recovery and reuse, respectively. One additional pilot refers to both water and material recovery. 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 what 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 is accessible on the ULTIMATE webpage in the case study section (https://ultimatewater.eu/demonstration-cases/). Currently, 20 pilots are operational and four pilot plants are still under construction. 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 M37.

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 are and 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*.

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

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

		Water Smart Industrial Symbiosis							Explanation of colour code/scale indication		
		Industrial Sectors				Service Providers			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**	AgroFood	Beverage	Chemical/Petrochemical	BioTech	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 adsorbent for wastewater treatment *TRL 4 → 7*
3	Rosignano (IT)								Advanced oxidation process pilot plant with advanced monitoring system using locally produced peroxides *TRL 4 → 6*		Use of industrial byproducts in a clari-flocculation plant *TRL 4 → 6*
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*

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

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: WATER RECLAMATION AND REUSE	NUTRIENT & MATERIAL RECOVERY & REUSE	ENERGY & HEAT RECOVERY & REUSE
	Explanation of colour code/scale indication								NO PILOT PLANT --> NOT PART OF D1.2	COMBINATION OF THE CS4 PILOT PLANTS FOR WATER & MATERIAL	
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 and utilisation for treatment steps *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*

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

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.

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. Operational demo cases

In ULTIMATE, 24 pilot plants are developed and will be demonstrated at nine case studies to showcase innovative circular economy solutions (Table 2). Furthermore, CS1 - CS8 conducted laboratory experiments, before they implemented their pilot plants. In total, 17 different laboratory experiments and/or investigations of already existing facilities were and still are accomplished to better understand the circumstances of the real environment and to learn more about the type of technology before the implementation and in parallel to the operation pilot-scale and full-scale plants.

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** and **material recovery**: Reclamation of greenhouse drain water using electrodialysis and 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 **Material recovery and reuse**: Advanced oxidation process pilot plant using locally produced peroxides with an advanced monitoring system **Material recovery and reuse:** Use of industrial byproducts in a clari-flocculation plant
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 carboni-sation demo plant **Water recovery**: Advanced oxidation & UV light treatment **Energy recovery**: Anaerobic membrane bioreactor **Energy recovery**: Solid oxide fuel cell **Energy recovery**: Pilot-scale and full-scale electro-stimulated anaerobic reactor (ELSAR)
CS6 Karmiel/ Shafdan (IL)	Wastewater from olive oil production, slaughter-houses 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. AC **Material recovery**: Plant to recover polyphenols

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

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**: Laboratory scale and full-scale 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 or open nanofiltration unit.

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

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

2.1. CS1: Tarragona

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
1	1.2.1	RO + MD; ammonia removal via zeolites	100%	100%	100%	Nov 22

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

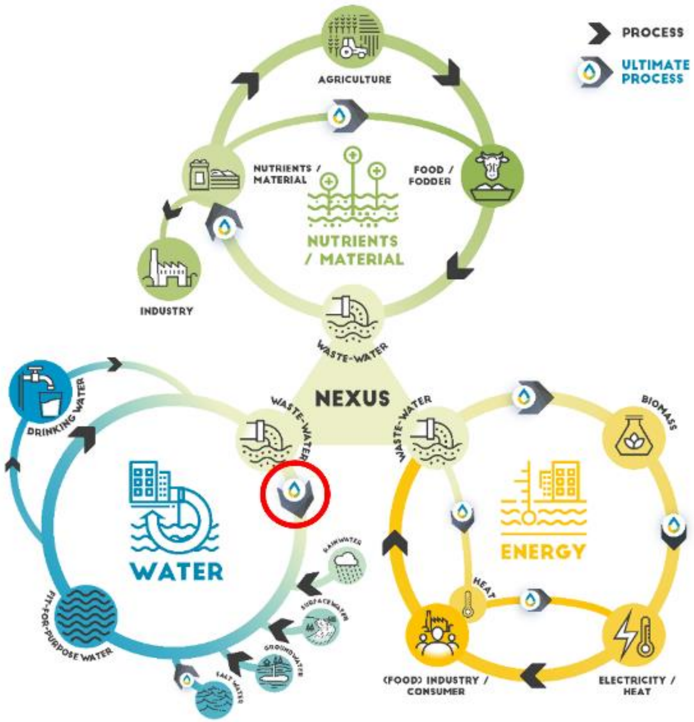
CS1: Tarragona

Lead partner:

eurecat
Centre Tecnològic de Catalunya

Other partners:

aitasa
Aguas Industriales de Tarragona S. A.



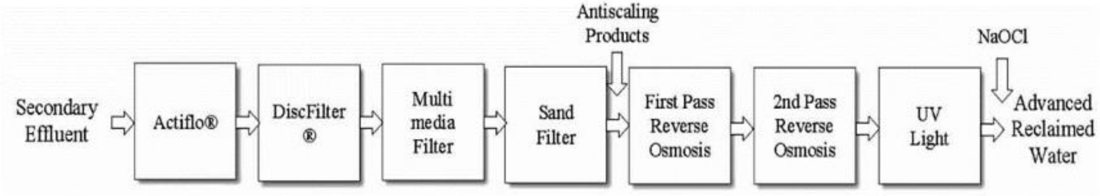
2

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

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

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.



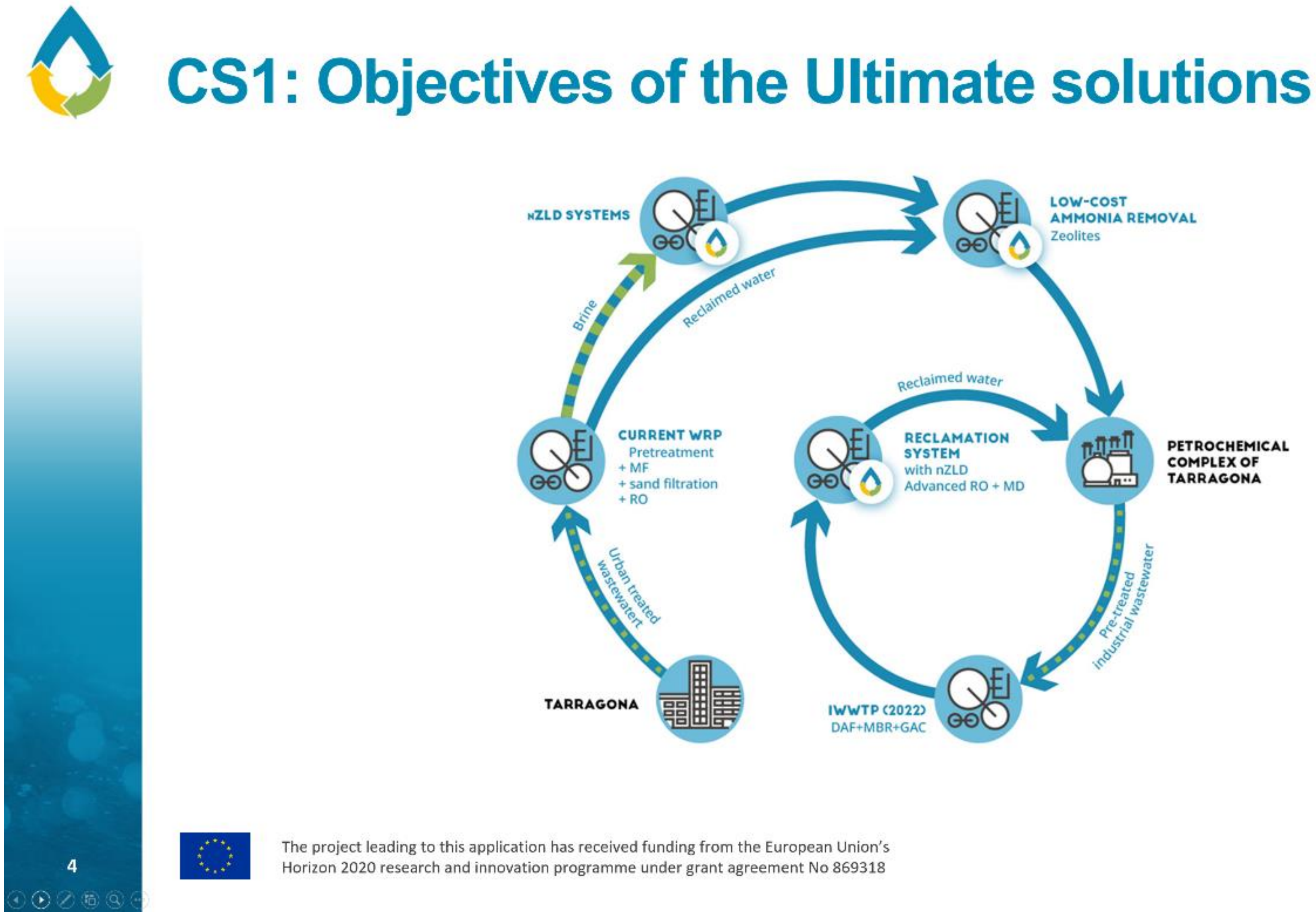
✓ On the other hand, in order to meet future water requirements (BREF limits), an **industrial wastewater treatment plant (iWWTP)** has been commissioned in April 2022 to polish the aggregated wastewater from the petrochemical complex and to produce reclaimed water for the complex (1348 m^3/h average 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)

3

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

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



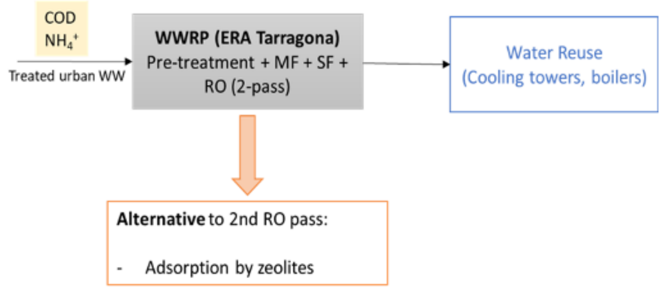
The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318

CS1: Objectives of the Ultimate solutions

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

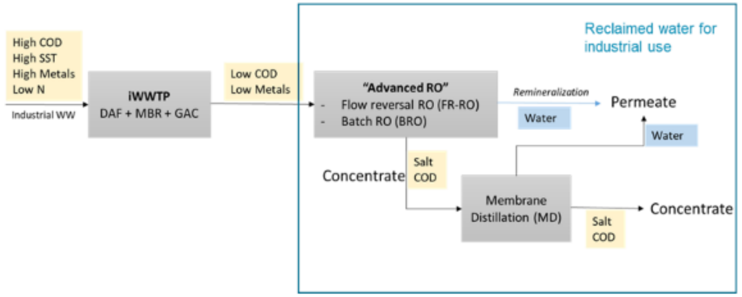
→ **Current WWRP**:
- → Increase water recovery of the current WWRP with nZLD technologies
- → Remove the ammonium with low-cost technology (zeolite adsorption)

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



ULTIMATE: removal of ammonia

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



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

5

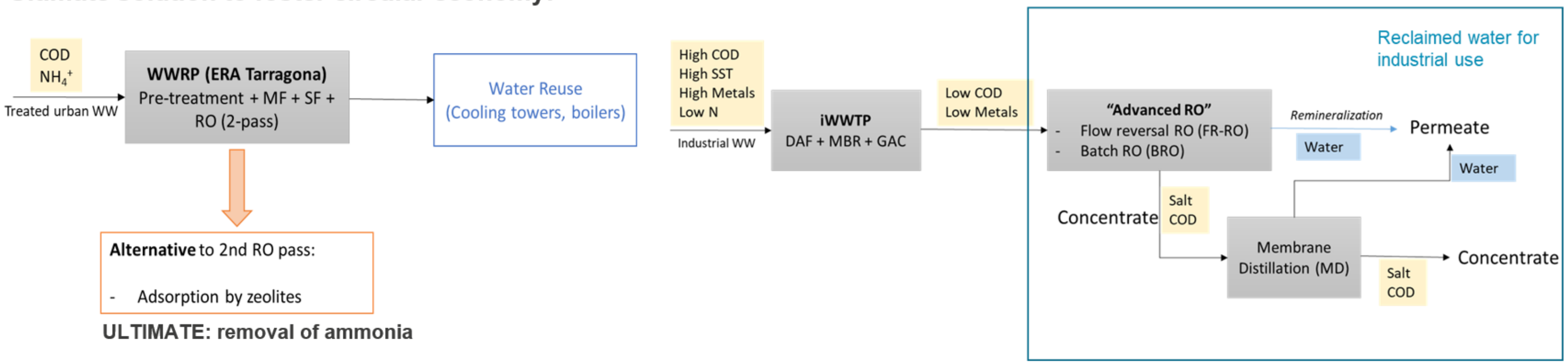
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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 since April 2022.

Ultimate solution to foster circular economy:

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



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

Capacity: 12 m³/day

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 plants operational: UF+RO+MD & Zeolites

6

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

CS1: Pictures/videos of the new technologies

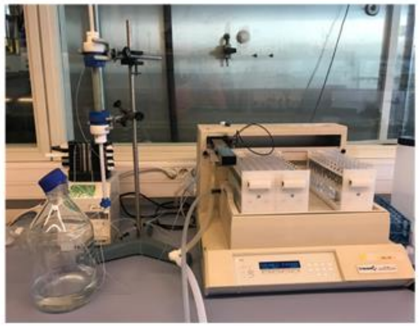
Subtask: 1.2.1 Increasing reclaimed water availability of the petrochemical complex of Tarragona (ES)

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

7

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

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

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:
  - All equipment from supplier 1 (UF+RO+zeolites) and supplier 2 (MD) delivered and installed in AITASA facilities.
  - Hydraulic tests with UF + RO units with clean water→ OK
  - Adsorption with zeolites equipment needs some modifications→ RO permeate storage tank (feed) and valves for sampling points.
  - Start-up with real water scheduled for 21st November week and training for all the technologies.

Maritim container and tanks

UF unit (left) and RO unit (right)

Adsorption with zeolites column

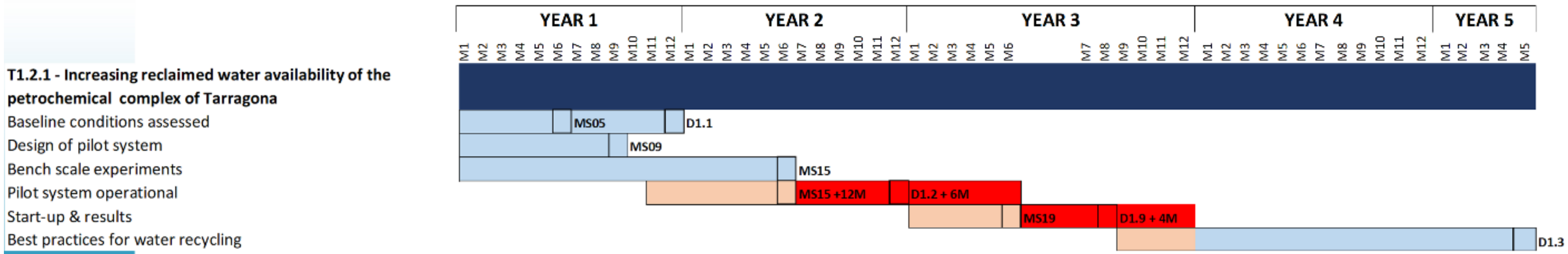
Operation monitoring

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

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

CS1: Task 1.2.1 – Timeline

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



→ **Pilot system is operational since November 2022 (M30)**

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

9

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

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

ULTIMATE
WATER SMART INDUSTRIAL SYMBIOSIS

CS1 Contacts

andrea.naves@eurecat.org
sandra.casas@eurecat.org

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

2.2. CS2: Nieuw Prinsenland

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
2	1.2.2	Reclamation of water using electrodialysis	75%	100%	100%	Nov 22
	1.3.1	Feasibility study: HT-ATES	No pilot plant --> excluded from D1.2			
	1.4.1	Recovery of nutrients: test beddings & demo greenhouse	75%	100%	100%	Nov 22

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

CS2: Nieuw Prinsenland

Lead partner:

KWR

Collaborators:

Coöperatieve Tuinbouw Water Zuivering
De Vlot

Glastuinbouw Nederland

NIEUW PRINSENLAND

GHENT UNIVERSITY

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

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

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:

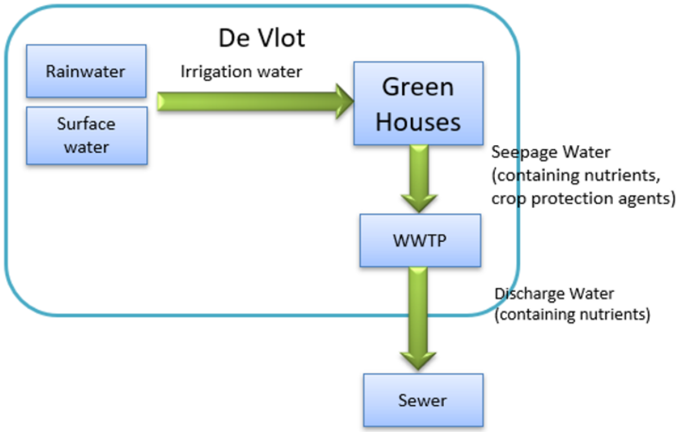
Prefiltration by vibrating and rotating filters: suspended solids removal

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



3

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

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

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

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).

5

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

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

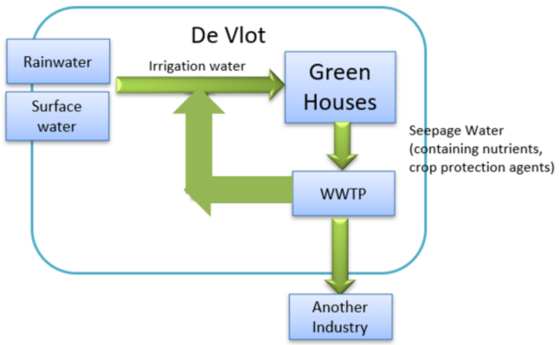
CS2: Subtask 1.2.2 Status/progress

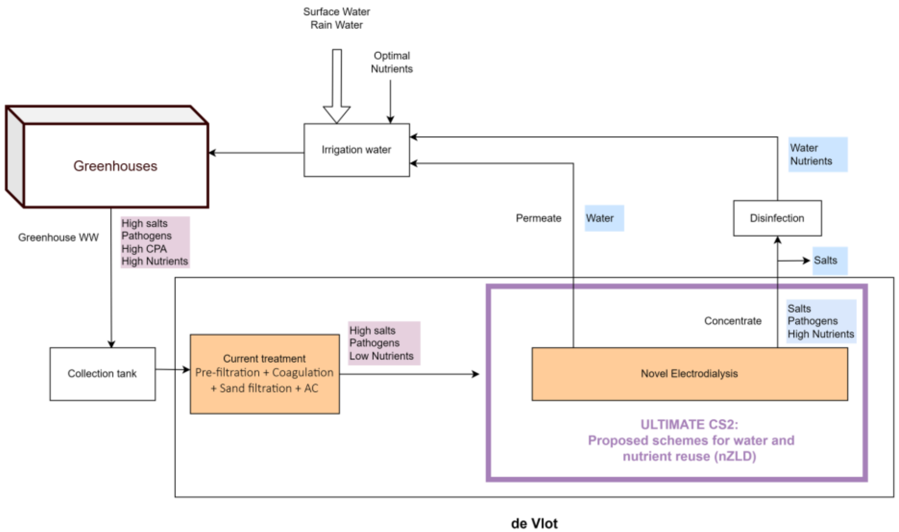
Subtask: 1.2.2 Optimising water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

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 – completed and pilot plant - operational

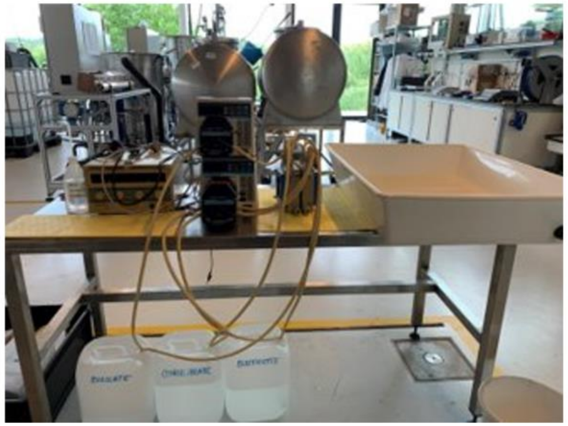
6

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

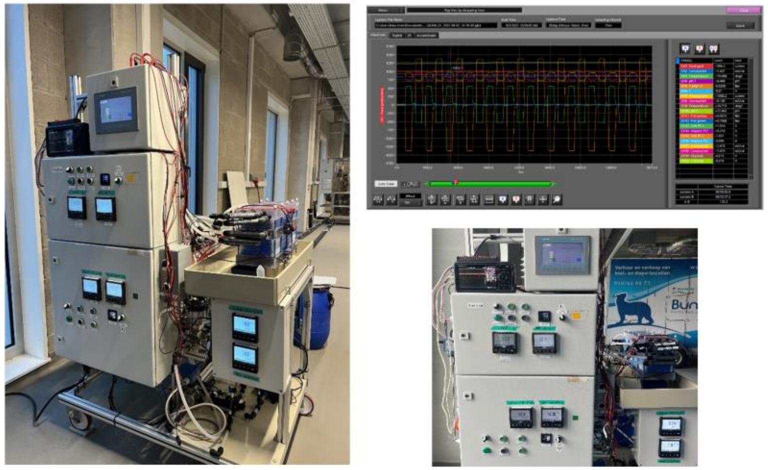
CS2: Pictures/videos of the new technologies

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



Pilot experiments ongoing at Ghent University

Lab experiments to continue for remainder of project to support pilot.

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

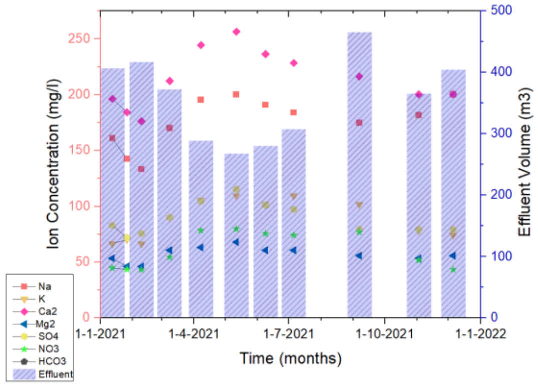
7

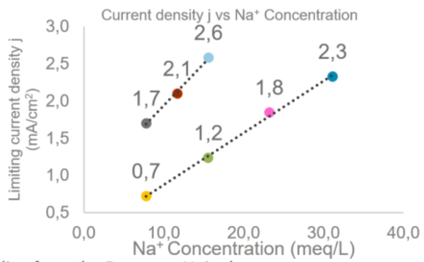
CS2: Results of the laboratory experiments

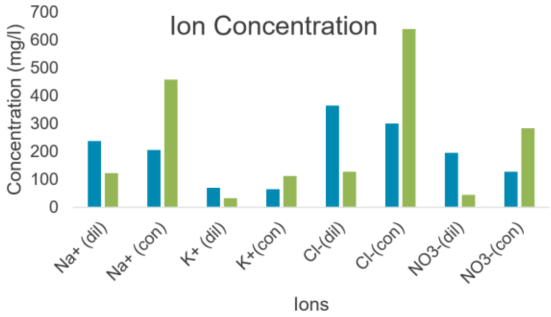
Subtask: **1.2.2 Optimising water reclamation from agro-food industries in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot**

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.

- 60% reduction in EC (1 ms/cm) (~50% Na removal)
- On-going optimization lab experiments with Greenhouse simulated and real wastewater







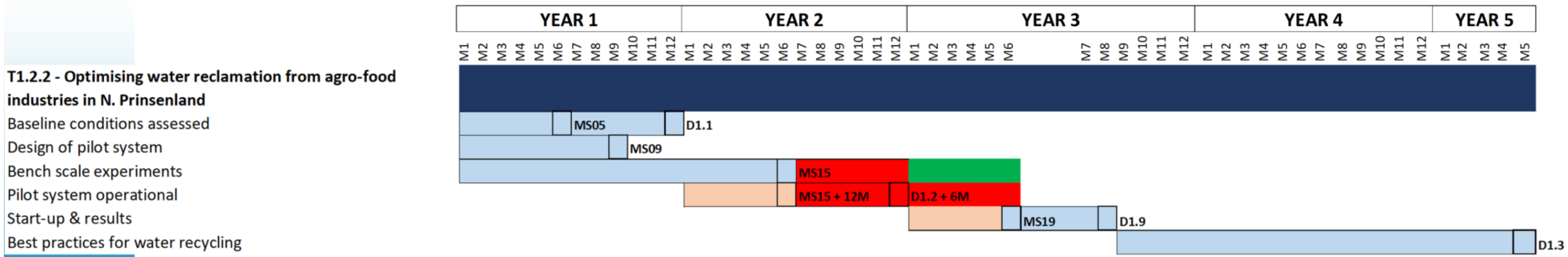
8

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

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

CS2: Subtask 1.2.2 – Timeline

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



→ **Pilot system operational since November 2022 (M30)**

→ **First results from pilot plant operation obtained**

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

Legend

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

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

9

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

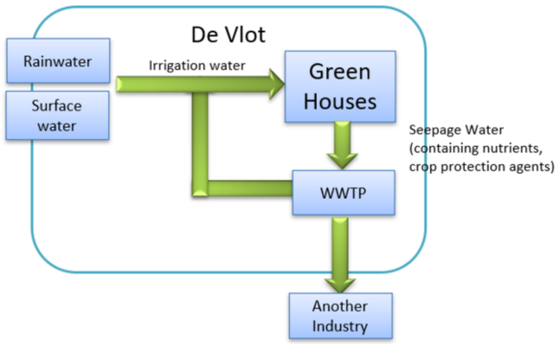
CS2: Subtask 1.4.1 Status/progress

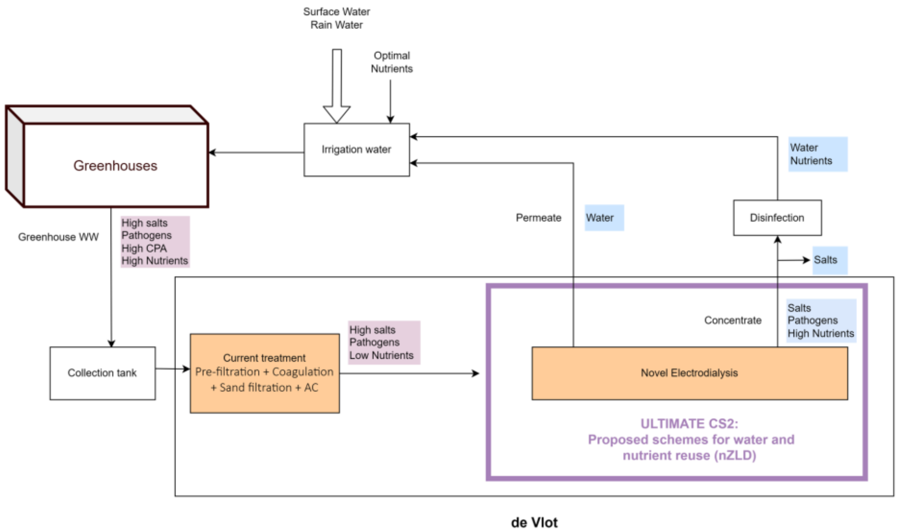
Subtask: 1.4.1 Recovery of nutrients from greenhouse wastewater in N. Prinsenland and Coöperatieve Tuinbouw Water Zuivering de Vlot

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:

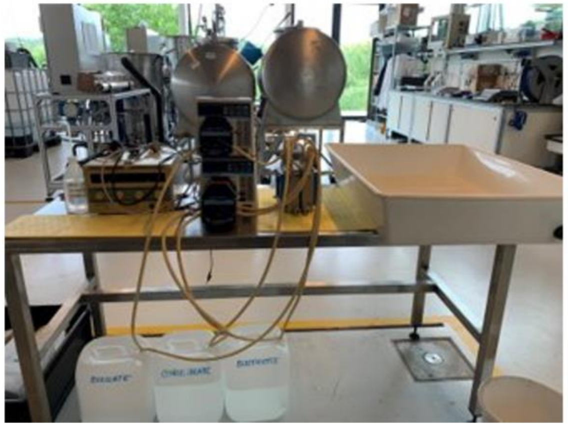
- **Performance validation for Proof of Concept on laboratory scale being finalized.**
- **Detailed pilot design – completed**
- **Construction of pilot plant – completed & pilot plant - operational**

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

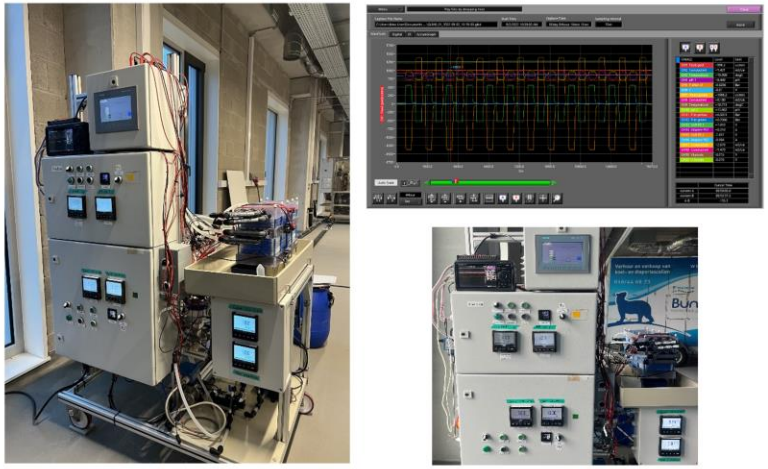
CS2: Pictures/videos of the new technologies

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



Pilot experiments ongoing at Ghent University

Lab experiments to continue for remainder of project to support pilot.

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

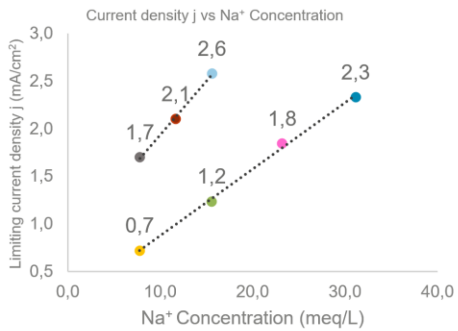
11

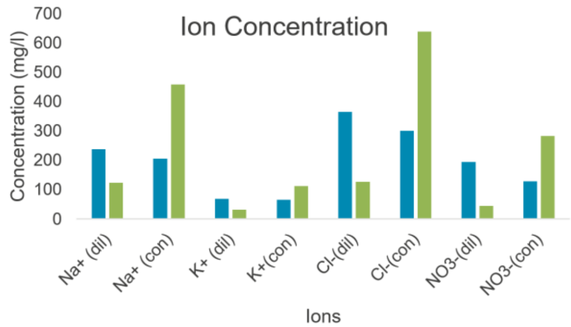
The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318

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, nutrient concentration and the removal of sodium is required. Thus, the described experiments in subtask 1.2.2 do also apply to this subtask 1.4.1.





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

12

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

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) Nutrient concentration
2) Efficiency in retaining nutrients (N, P, K) in the matrix and sodium removal
3) Optimal operational conditions and energy requirements

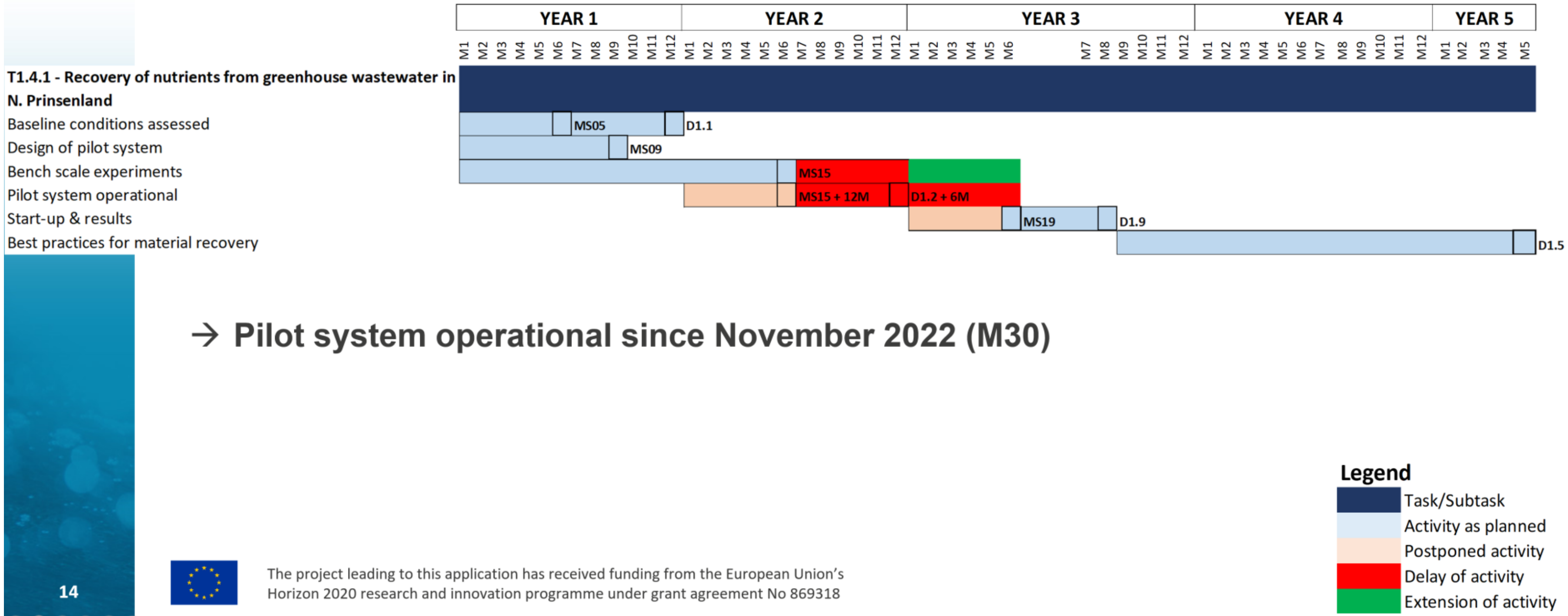
13

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

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

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 operational since November 2022 (M30)**

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

14

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS2 Contacts

Tavishi.Guleria@kwrwater.nl

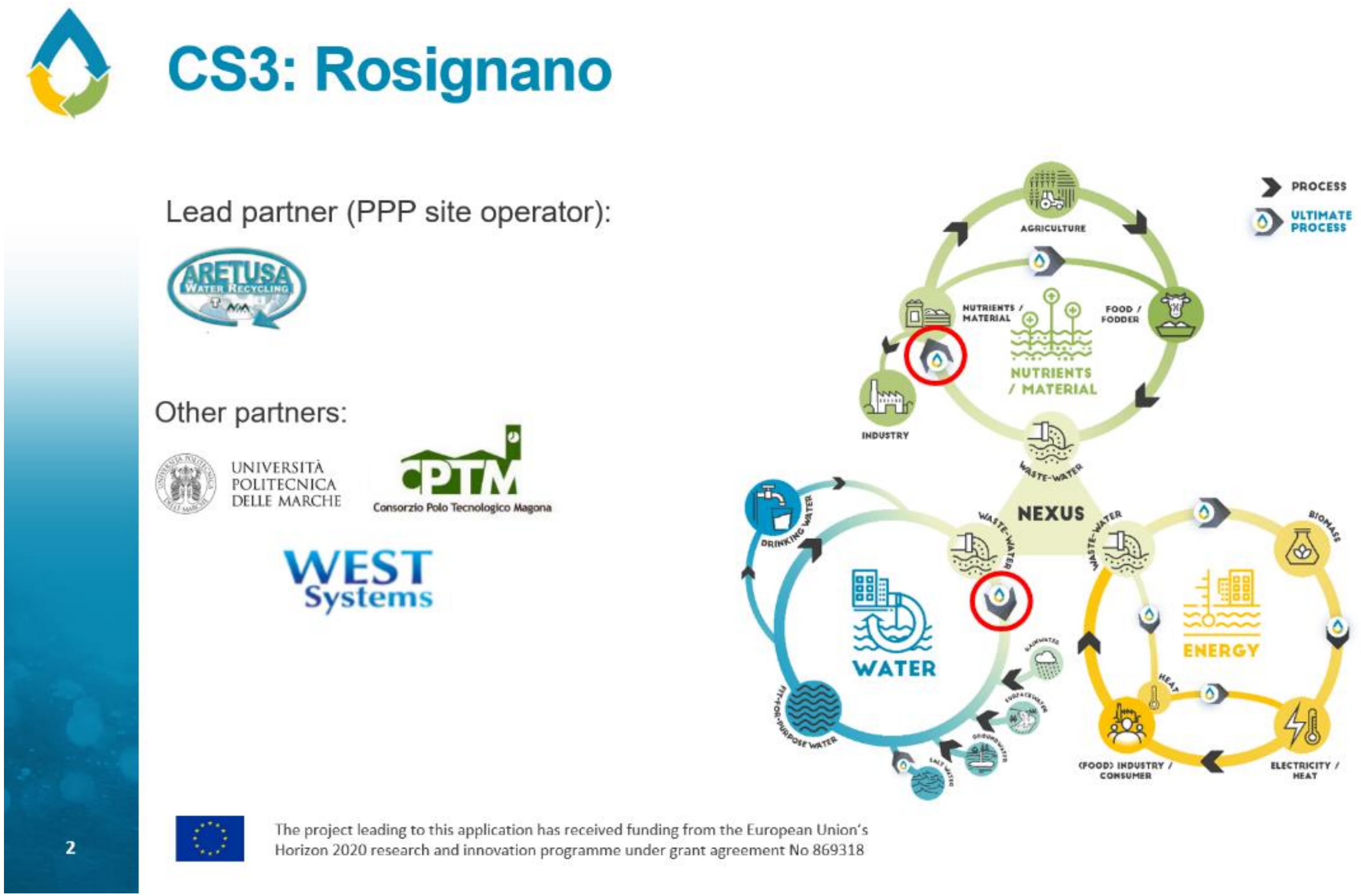
Joep.van.den.Broeke@kwrwater.nl

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

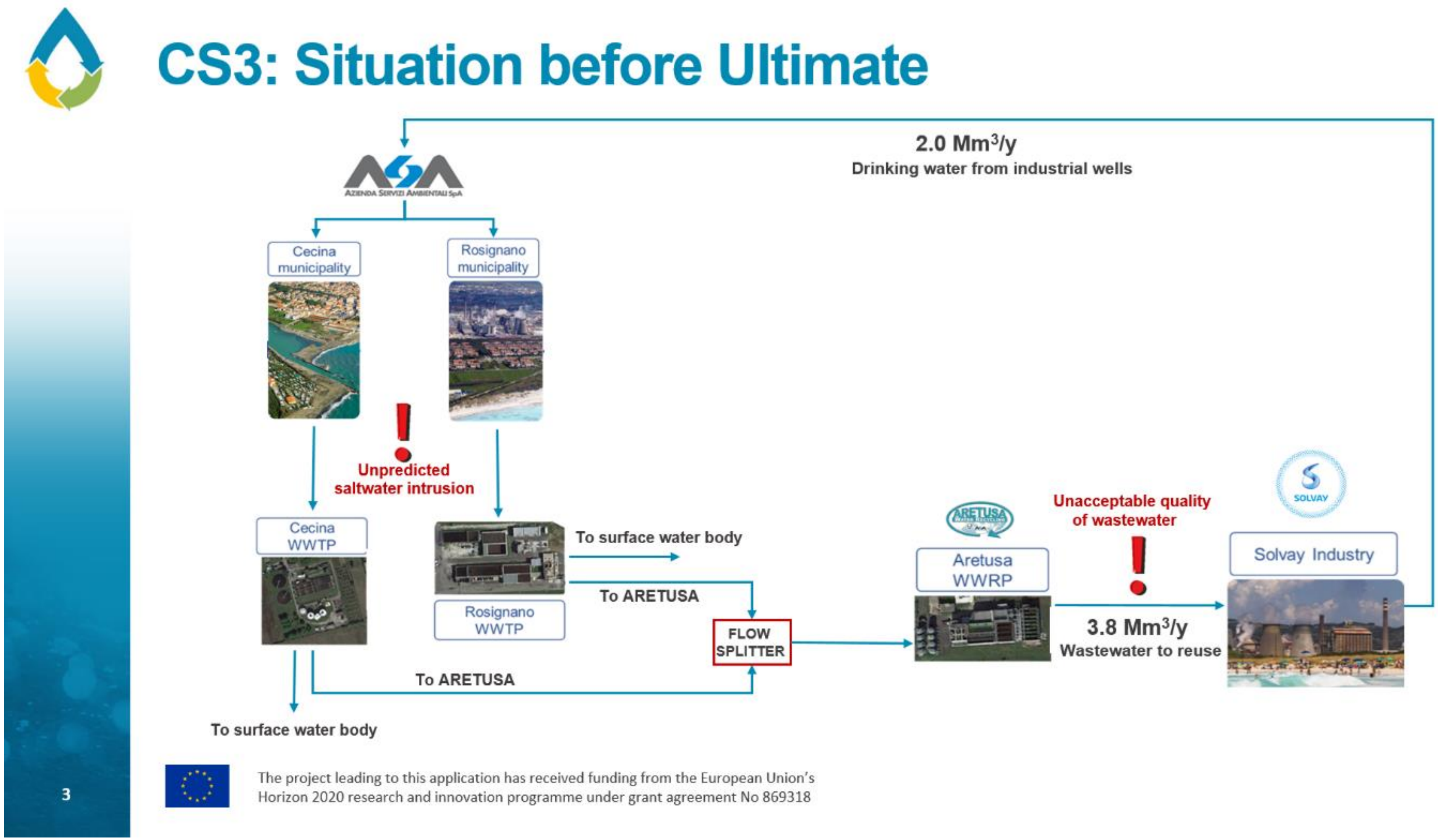
2.3. CS3: Rosignano

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 avoid high chlorine concentrations	No pilot plant --> excluded from D1.2			
	1.4.2	Use of byproducts: pilot scale adsorption system	100%	100%	100%	Jul 22
		Use of byproducts: clari-flocculation pilot	100%	10%	0%	Jan 24
		AOP pilot system	60%	100%	0%	Jun 23

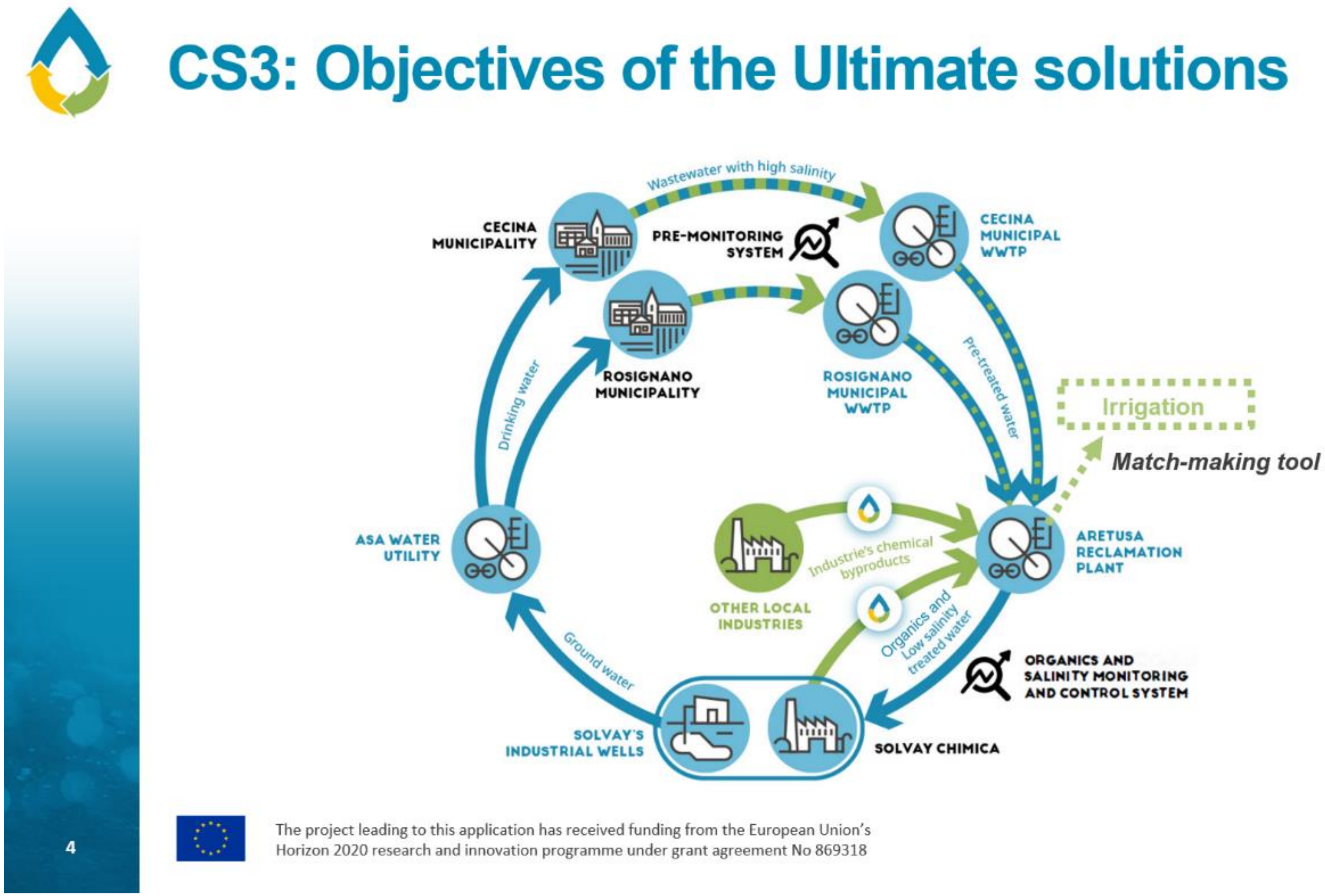
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318



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



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



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

CS3: Subtask 1.4.2 Status/progress

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

Baseline technology: No material reuse is in place so far

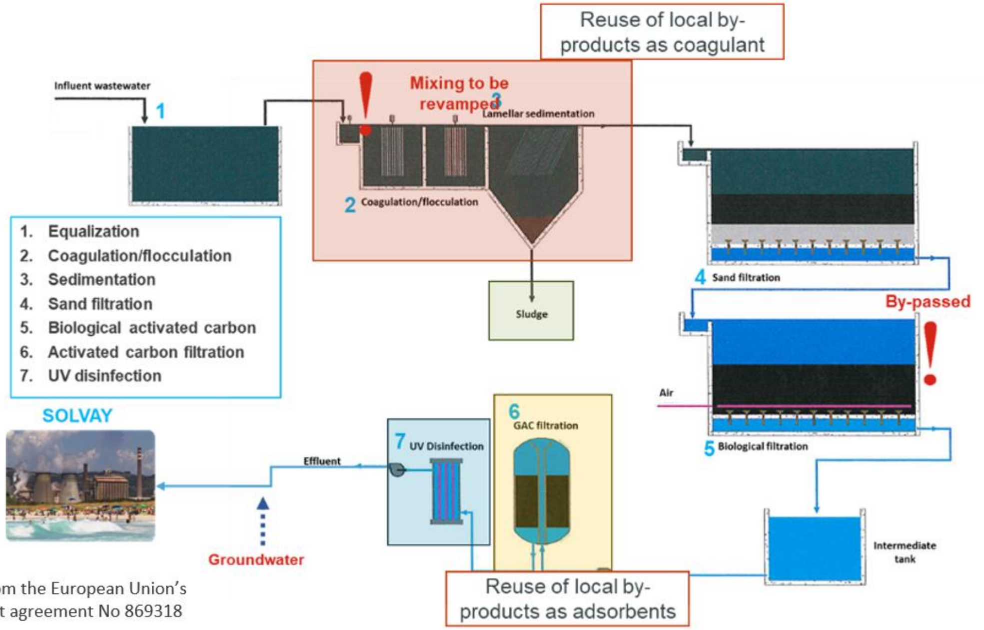
Ultimate solution to foster circular economy: Adsorption pilot with alternative GAC, and AOP pilot

TRL: 4 → 7

Capacity: < 50 m^3/h

Quantifiable targets: > 10% material recovery

Status/progress:
- Detailed design completed
- Adsorption pilot completed & in operation
- AOP pilot under construction
- Clari-flocculation plant under construction



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

5

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

CS3: Results of the functional test

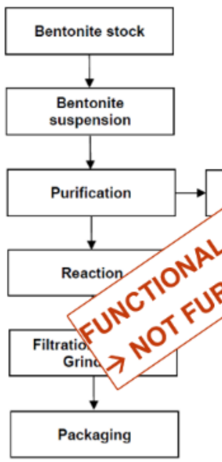
Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

MATERIALS (BY-PRODUCTS) CARACTERIZATION

ORGANOCLAY (LAV1)

Laviosa Chimica Mineraria SpA extracts, process and distributes industrial mineral products, in particular bentonitic products and special 'modified' b… tic 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



…zione ai raggi X dimostrano che la fase più abbondante risulta quella …no 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

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

6

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

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

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

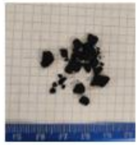
Physical activation – ATT1

- 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

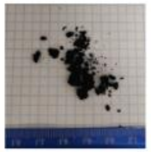
- Impregnation of char pellets in KOH aq. solution (KOH to char ratio: 1:1) at 60°C for 6 hr.
- Drying of the impregnated char at 105°C.
- Heating in a tubular oven up to 600°C (5°C/min), isotherm at 600°C for 1 hr and cooling (5°C/min) with N2 purging.
- Washing with 1M HCl and demi water (up to pH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

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

7

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

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

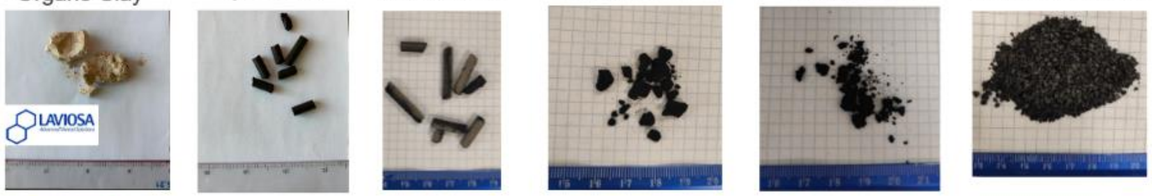
	LAV1	HC	HC ATT1	HC ATT4	HC ATT5
F^-	< 0.1	54.2	0.2	0.4	< 0,1
Cl^-	2,5	44.4	62.5	26.4	1.7
$NO3^-$	0.2	1.3	< 0,1	< 0,1	< 0,1
$PO4^{---}$	3.2	38.5	< 0,1	54.3	8.4
$SO4^{--}$	32.9	147.3	143.9	110.2	103.4
COD	81	4200	< 15	< 15	< 15

- ✓ *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



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

8

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

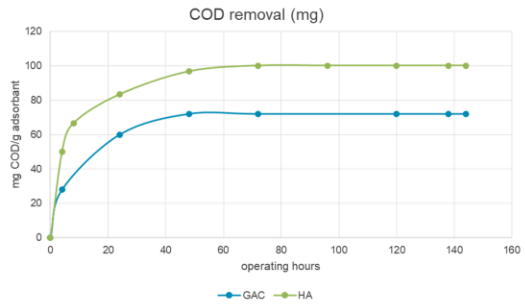
CS3: Results of the functional test

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

ADSORPTION TESTS

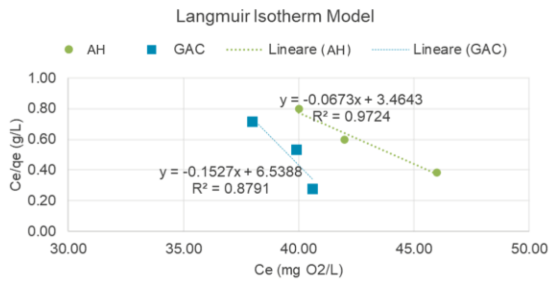
Material tested: Activated Hydrochar (AH) and Commercial Granular Activated Carbon (GAC)

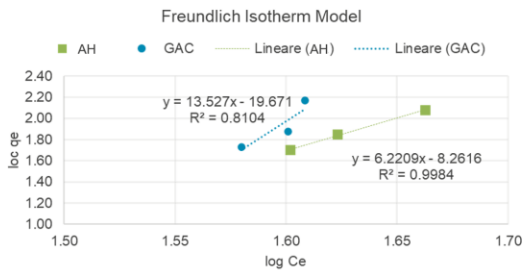
KINETIC AND ISOTHERM FOR COD ADSORPTION IN MUNICIPAL WASTEWATER



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.***
- ✓ ***Adsorption processes in both AH and GAC can be described by Pseudo Second Order kinetic model, while the Langmuir Isotherm model showed a better fit than the Freundlich model.***
- ✓ ***100 mg and 70 mg of COD was removed by AH and GAC respectively after 72 operating hours.***

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

9

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

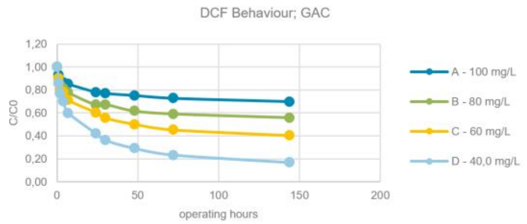
CS3: Results of the functional test

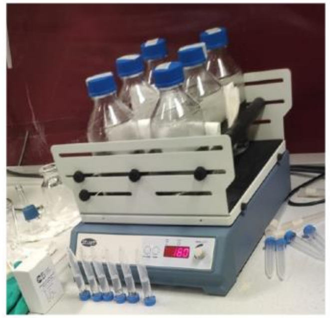
Subtask: 1.4.2 Use of by-products of local industries for wastewater treatment in Rosignano

ADSORPTION TESTS

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

KINETIC WITH DICLOFENAC SOLUTION



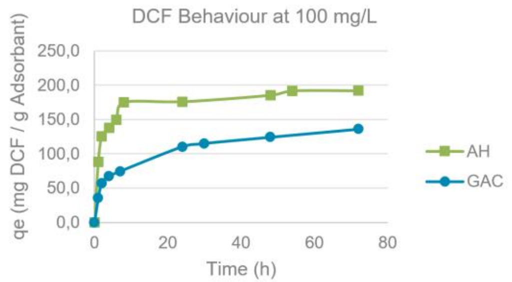


Experimental Setup for Batch Tests

- ✓ ***AH showed higher adsorption capacity than conventional GAC.***
- ✓ ***The adsorption equilibrium was reached, after 72 operating hours for HTC and after 144 hours for GAC***

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



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

10

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

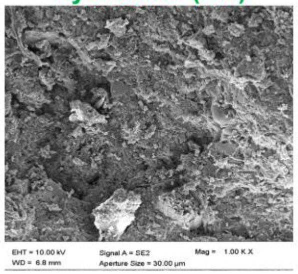
CS3: Results of the functional test

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

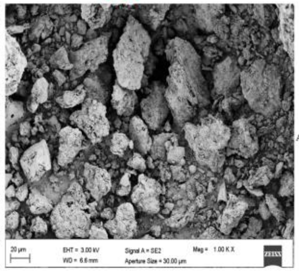
ADSORPTION TESTS

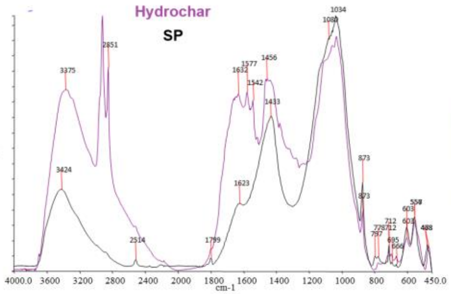
Material tested: Pyrolyzed Hydrochar (PH) and Commercial Granular Activated Carbon (GAC)

Hydrochar (HC)



PH





- ✓ *Pyrolyzed hydrochar (PH) is much more chopped and less compact.*
- ✓ *Thermal process effectively eliminated the organic part (TAR) from the material.*

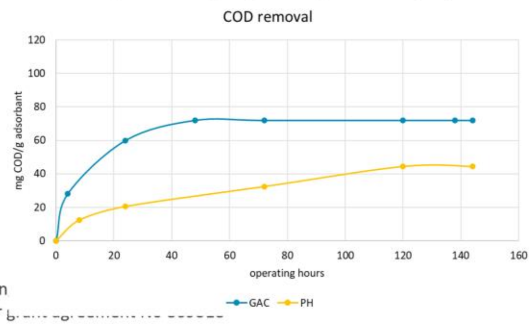
MATERIALS		HC	AH	PH	GAC
BET surface area	m2/g	ND	751.7	100.42	1100-1150
Maximum pore volume	cm3/g	ND	0.359	0.045	-
Median pore width	Å	ND	16.08	7.672	-

KINETIC WITH MUNICIPAL WASTEWATER

Adsorption on Activated Hydrochar (AH)

KINETIC	EQUATION	PARAMETERS		GAC	SP
Pseudo-First Order	$\log(qe - qt) = \log(qe) - \frac{k_1 t}{2.303}$	k1	min^{-1}	0.164	0.0452
		R²		0.987	0.90
Pseudo-Second Order	$\frac{t}{qt} = \frac{1}{k_2 qe^2} \frac{t}{qe}$	k2	g/mg/min	0.003	0.0093
		R²		0.999	0.90

Adsorption on Pyrolyzed Hydrochar (PH)



- ✓ *PH has a slower adsorption kinetic of COD compared with AH and GAC. Lower COD removal was observed.*

11

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

CS3: Results of the functional test

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

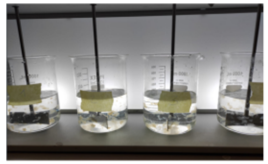
MATERIALS (BY-PRODUCTS) CARACTERIZATION

- ✓ "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	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	Precotto	8-9.5	49-58	0	17-24
Effluent wastewater	Precotto	8-9.5	25-40	7-19	0
Effluent wastewater	Soda Solvay	8-9.5	< 10	0	7-45
Aretusa wastewater	Precotto	9-9.5	7-47	9-11.4	5.7-9
Aretusa wastewater	Soda Solvay	9-9.5	47-73	0-8.4	9-24
Aretusa wastewater	Precotto and Soda Solvay	9-9.5	80-87	4-6.2	10-24



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

12

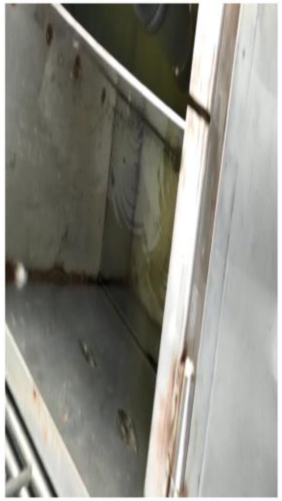
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

CS3: Pictures/videos of the new technologies

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

ADSORPTION PILOT SYSTEM START-UP



o this application has received funding from the European Union's
ch and innovation programme under grant agreement No 869318

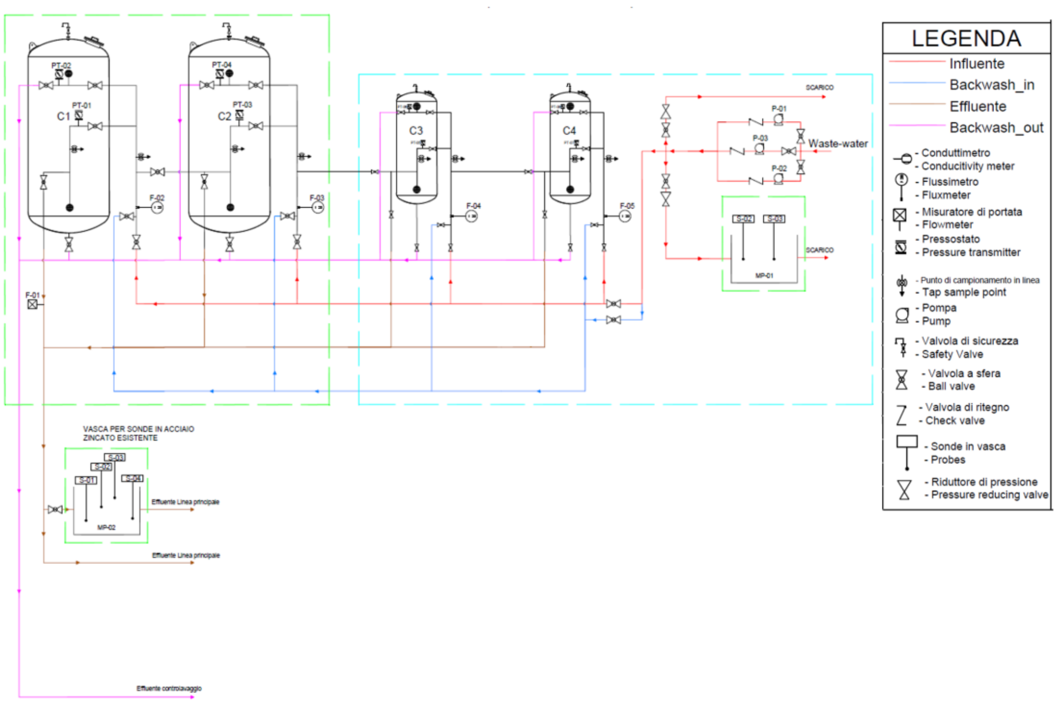
14

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

CS3: Operational procedures and methodologies

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

ADSORPTION PILOT SYSTEM



- Pilot plant has been designed to **use adsorption 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

15

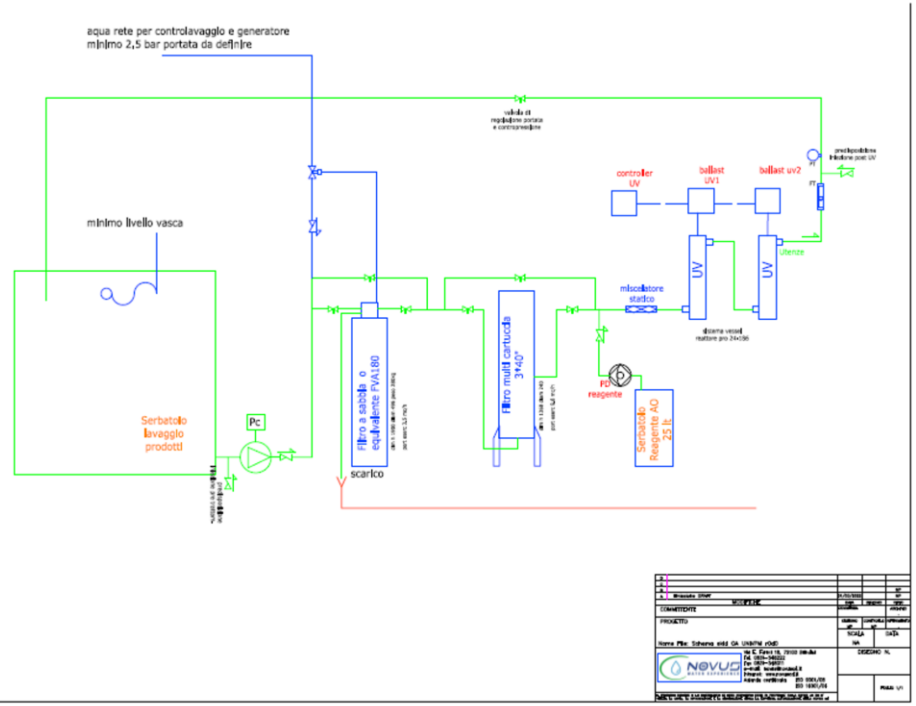
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

CS3: Operational procedures and methodologies

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

AOP PILOT SYSTEM



SKID EQUIPPED WITH:

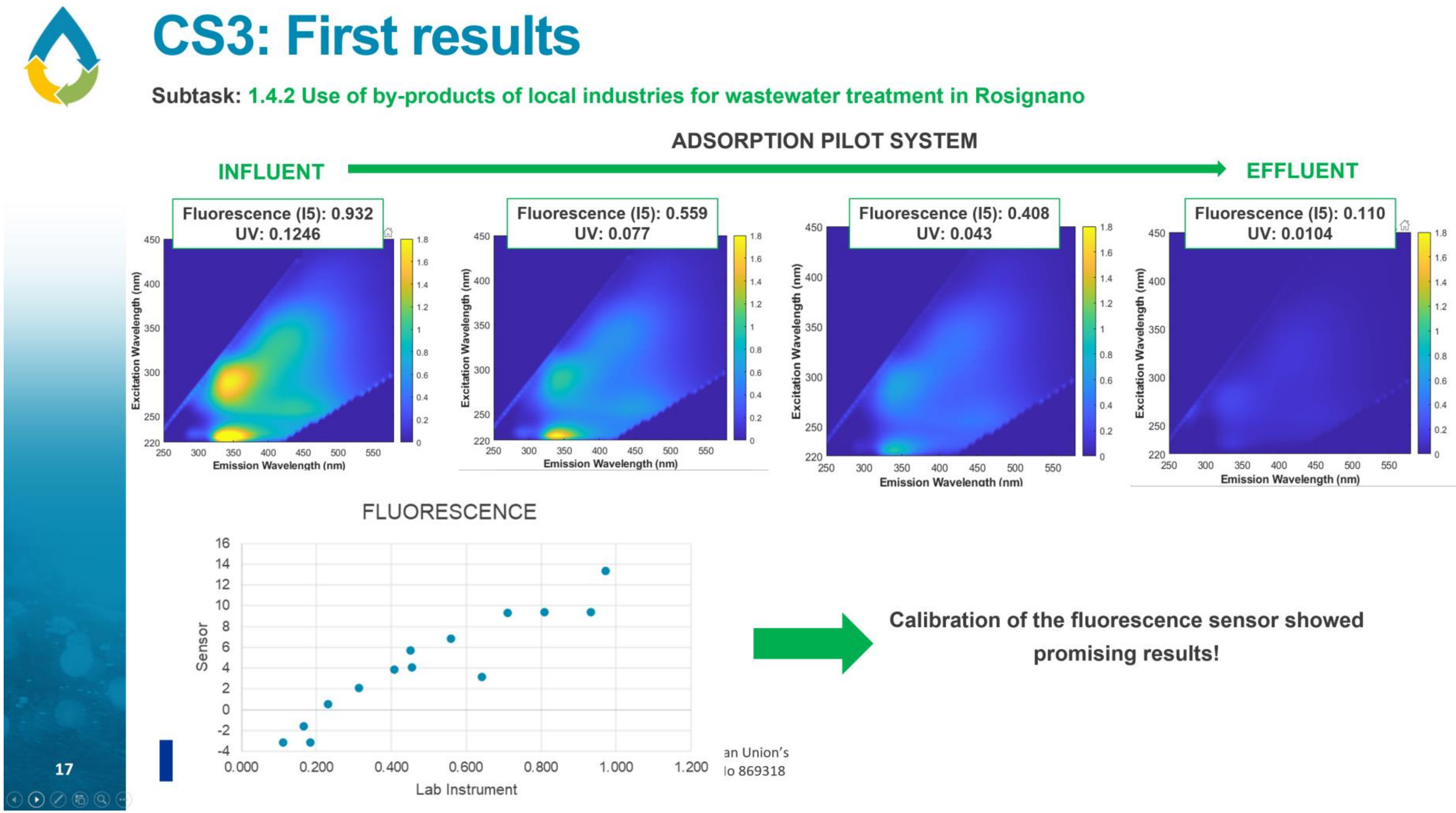
- ✓ pressurization pump: 60 l/min, 1.9 bar
- ✓ sand filter: 3.5 mc/h 250 kg of sand
- ✓ multi-cartridge filter
- ✓ electromagnetic dosing pump
- ✓ static mixer
- ✓ Viqua PRO 24-180mJ UV system
- ✓ electrical panel

Pilot plant under construction!

16

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

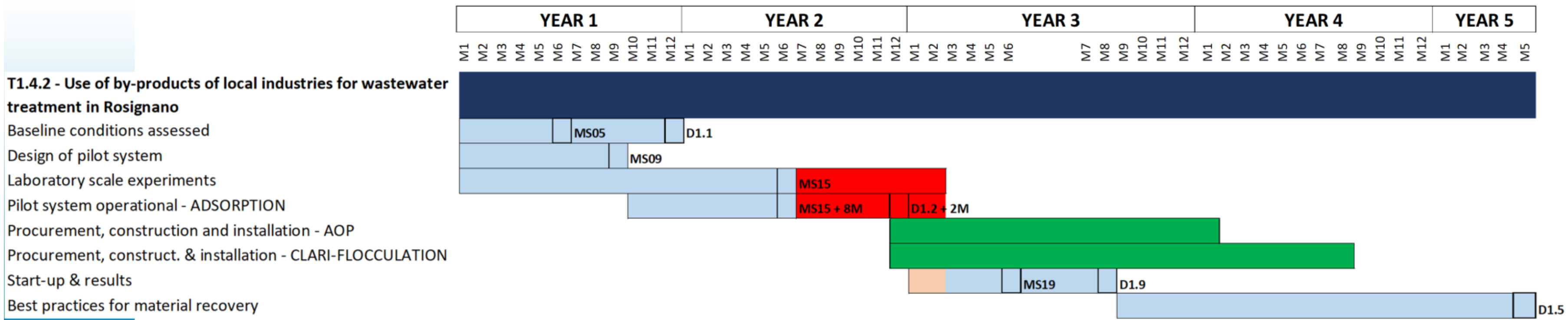
The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318



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

CS3: Subtask 1.4.2 – Timeline

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



→ **Pilot system is operational since July 2022 (M26)**

→ **Two additional pilot systems will be implemented having a different timeline**

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

→ **Additional pilots will be presented in D1.5**

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

18

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

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS3 Contacts

f.fatone@univpm.it

c.bruni@pm.univpm.it

m.sgroi@univpm.it

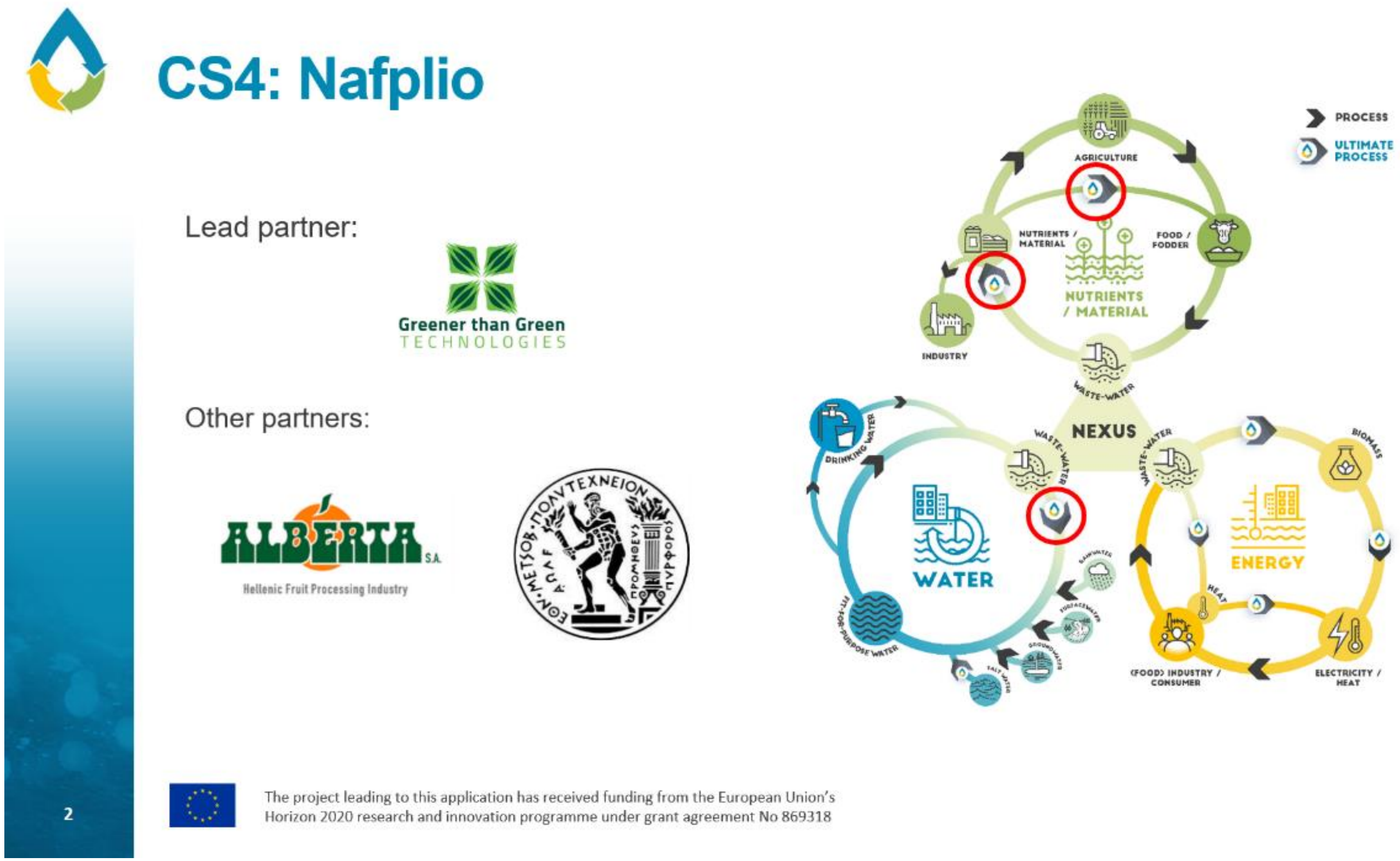
mattiaciampechini@gmail.com

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

2.4. CS4: Nafplio

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
4	1.2.4	Water recovery: filtration, AOP, SBP	100%	100%	100%	May 22
	1.4.3	Recovery of antioxidants: adsorption/extraction	100%	100%	100%	Nov 22

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



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

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

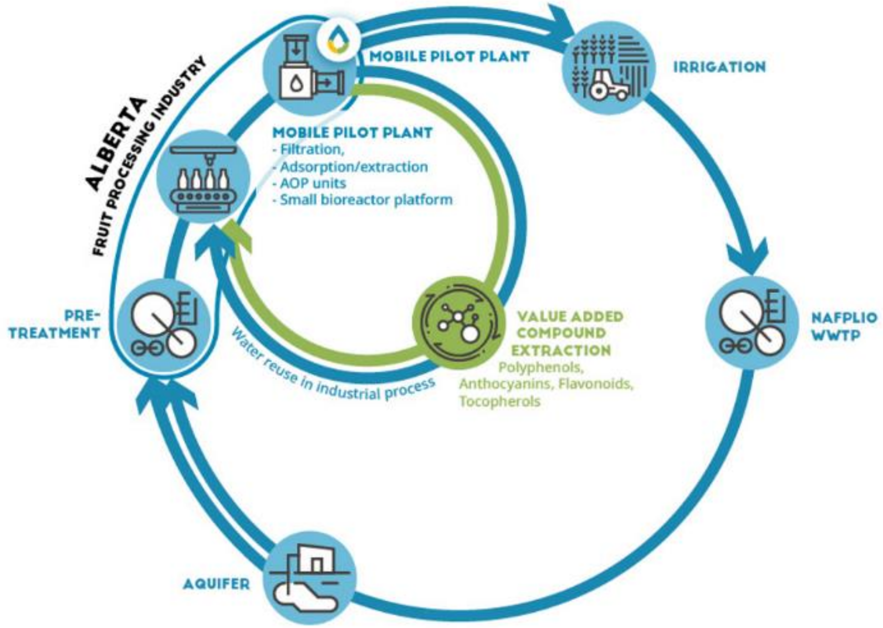
→or for reuse in the production procedure of Alberta S.A.

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

3

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

CS4: Objectives of the Ultimate solutions



4

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

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

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.

5

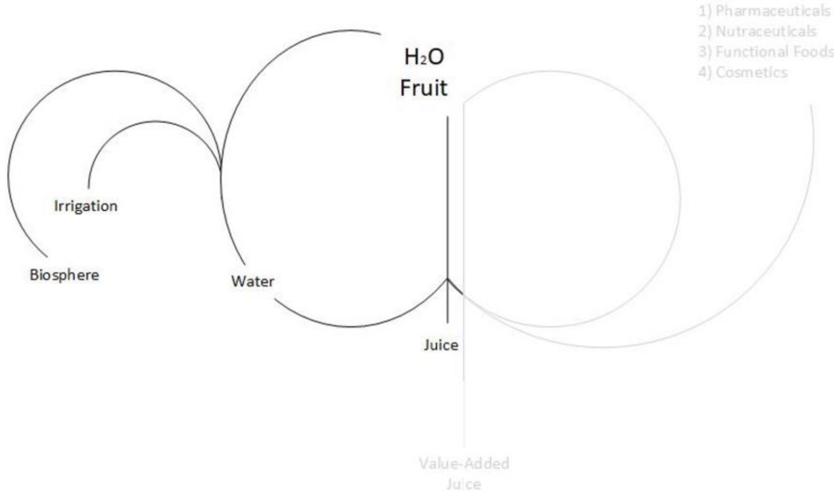
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

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

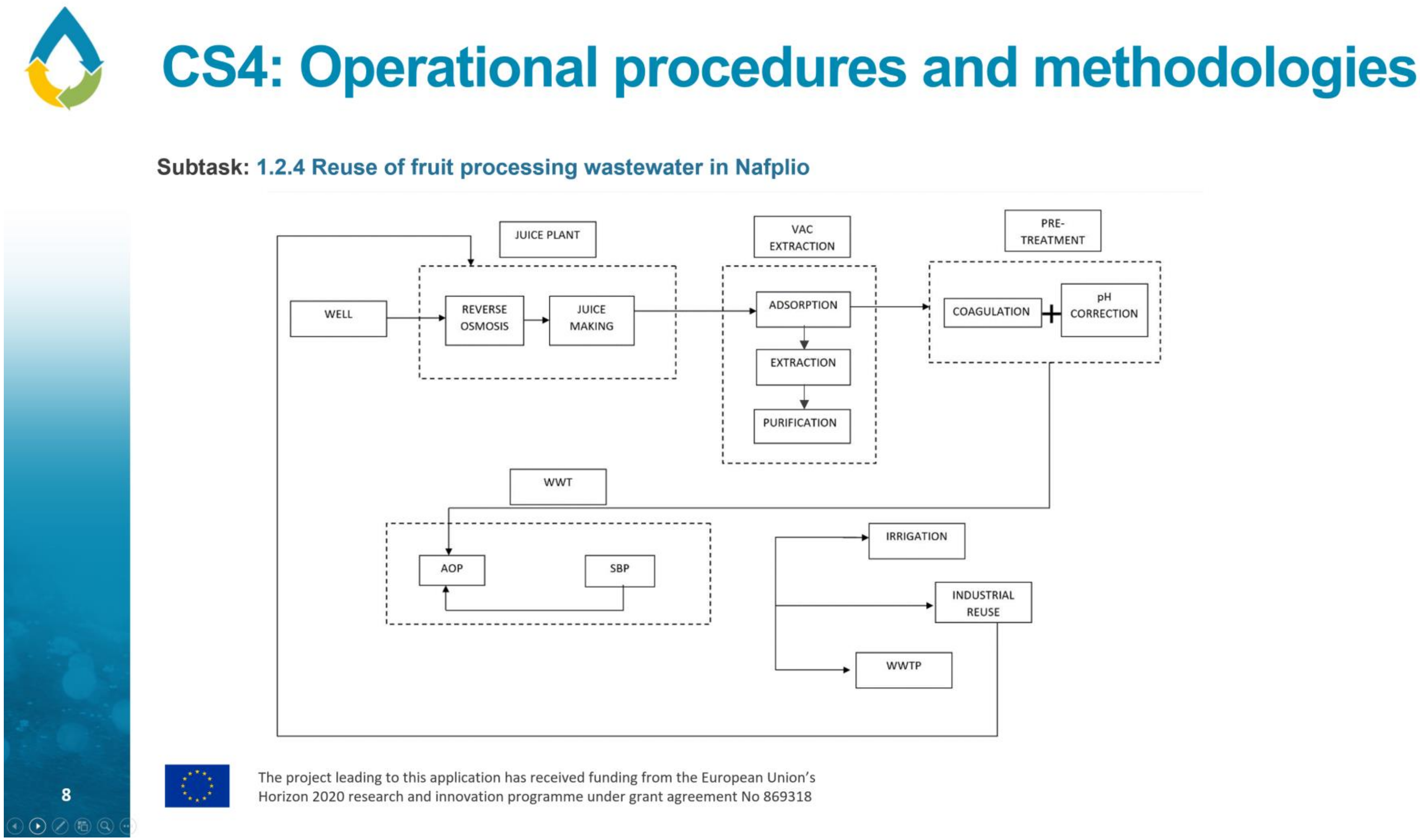
Quantifiable target: Ambition beyond the project: 100% water reuse for irrigation; >90% reduction of freshwater through water reuse

Status/progress:

- detailed design completed
- The unit has been installed in Nafplio and is operational

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


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
Unit installation video
TOC analyzer
Sievers InnovOx
On-Line TOC Analyzer
Sensors
Pi
CRIUS 4.0
SBP capsules
7
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



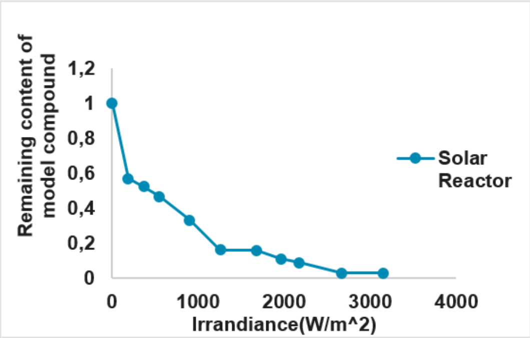
The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318

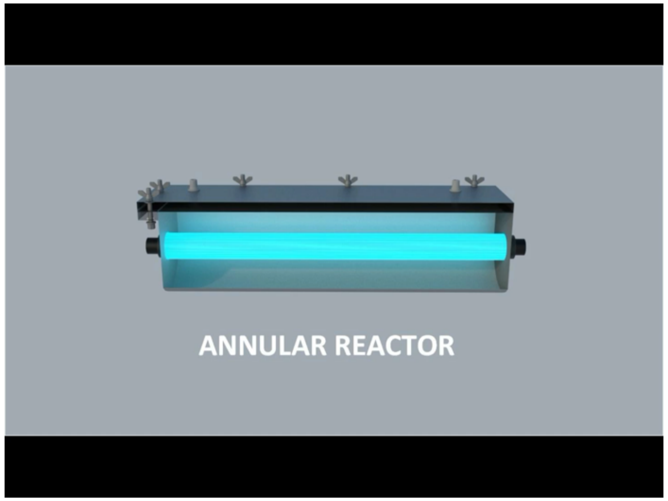
CS4: Results of laboratory experiments

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

Advanced Oxidation Process (AOP)

- **GtG has developed 2 AOP reactors**
- **Annular reactor:** a tube with a high intensity UV lamp where the wastewater flows through
- **Solar reactor:** made of quartz glass tubes and performs under solar light. It has been proven to effectively degrade our model compound





Solar reactor: low OpEx as there are no energy costs, but to achieve the contact time needed for degradation you need either huge area of glasses either extremely low flow, these are obstacles for a pilot unit

Annular reactor: operates with UV lamps and shorter contact time is needed

9

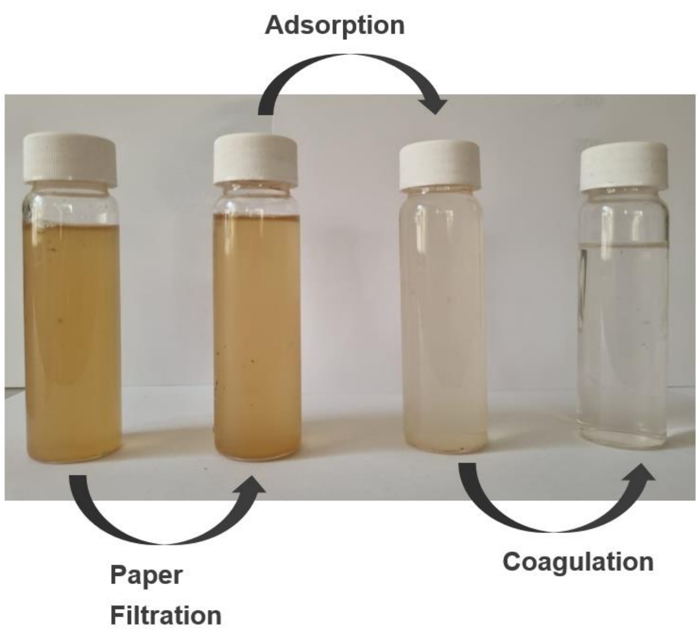
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

CS4: Results of laboratory experiments

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

Pretreatment steps- Orange by-product



	TOC (mg/L)
Orange by-product	1950
Filtrate (paper filtration)	1810
Solution after adsorption	1400
Coagulation supernatant	1005

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

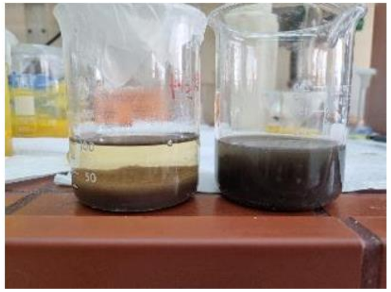
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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



11

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

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

CS4: Pictures of the pilot units

Subtask: 1.2.4 Reuse of fruit processing wastewater in Nafplio

Adsorption of polyphenols

AOP: Annular reactor

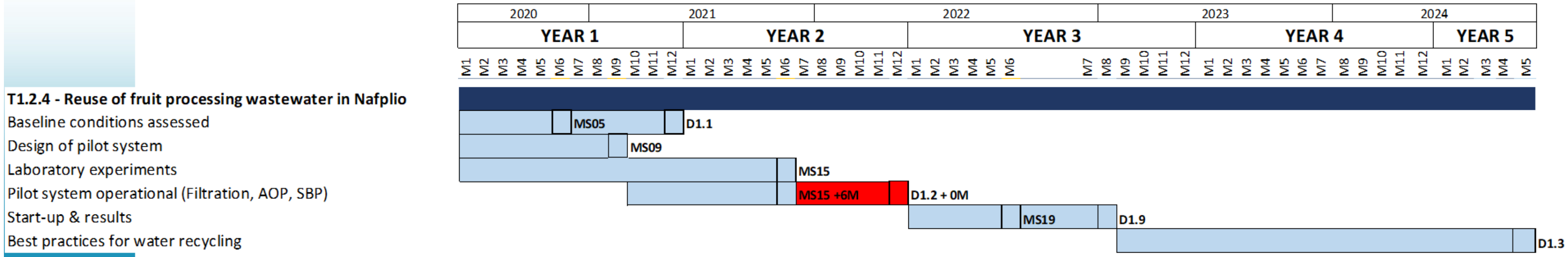
AOP: solar reactor

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

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

CS4: Subtask 1.2.4 – Timeline

Subtask: **1.2.4 Reuse of fruit processing wastewater in Nafplio**



→ **Pilot system (filtration, AOP and SBP) is operational since M24 (May 2022)**

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

13

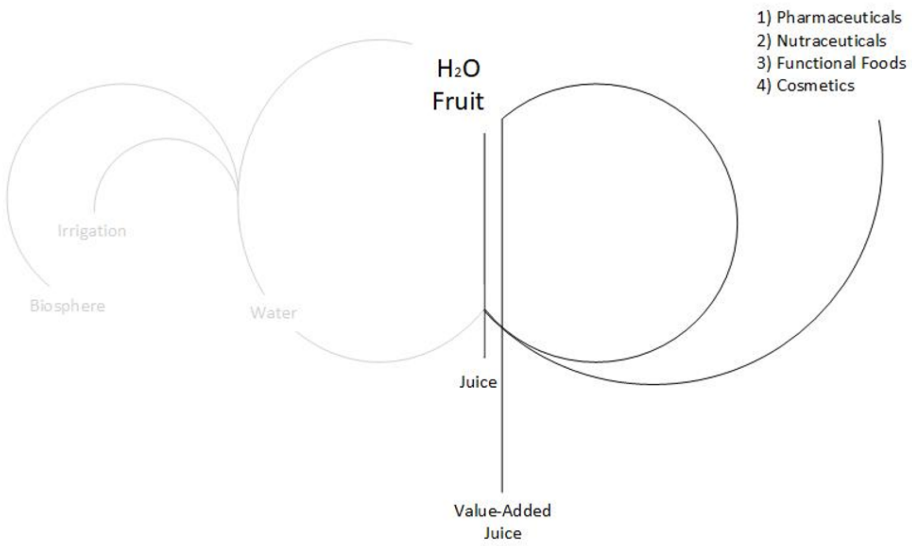
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

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 constructed and in operation

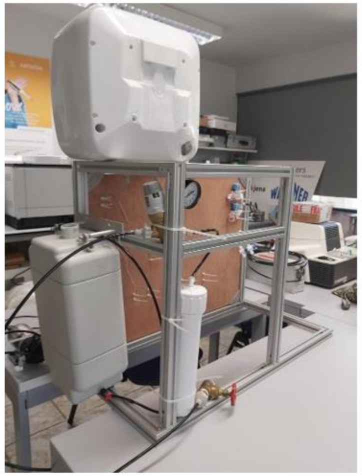
14

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

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

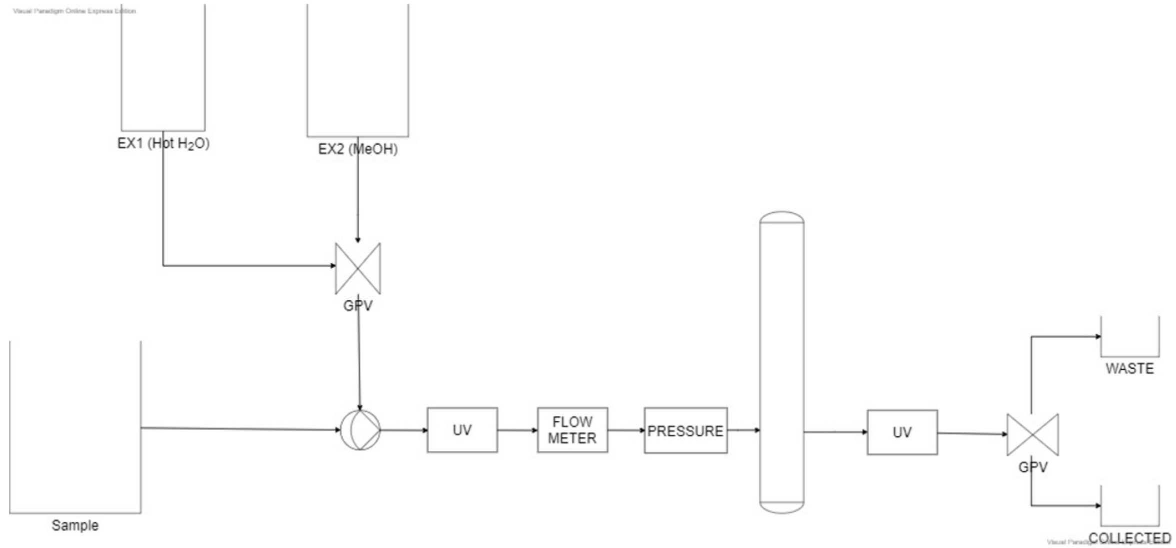
15

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

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

CS4: Operational procedures and methodologies

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



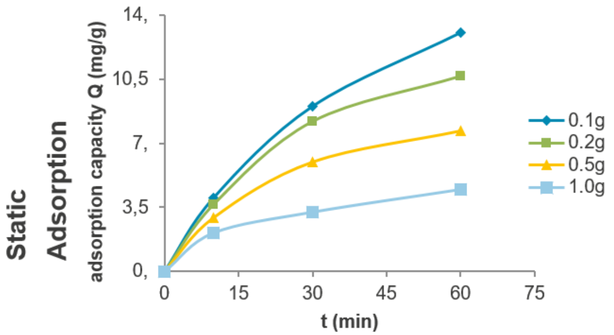
16

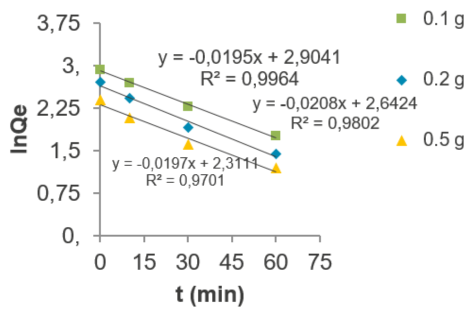
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

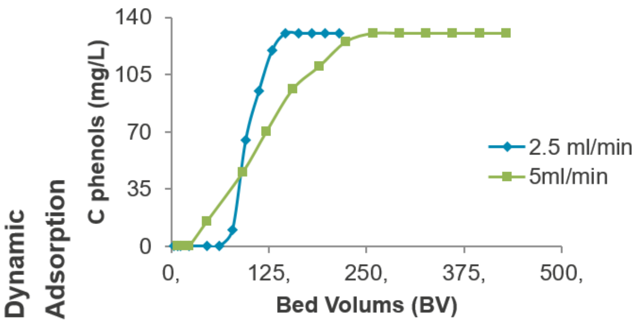
CS4: Results of the laboratory experiments

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

17

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

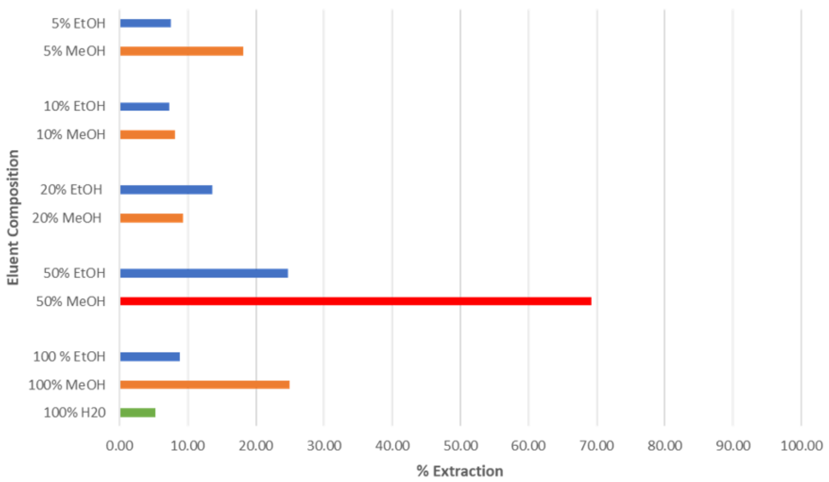
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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



18

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

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

CS4: Pictures of the pilot units

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

Adsorption of polyphenols

Supercritical water extraction

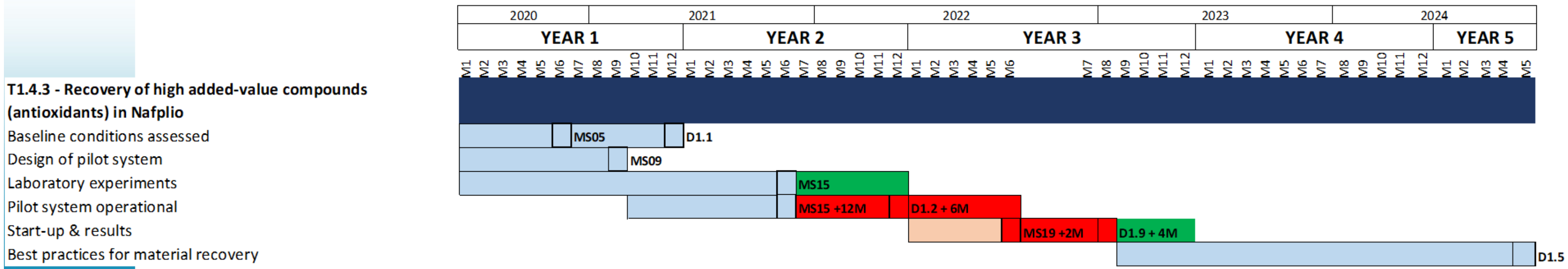
19

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

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

CS4: Subtask 1.4.3 – Timeline

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



→ **Pilot system operational since November 2022 (M30)**

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

20

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

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS4 Contacts

d.iossifidis@greenerthangreen.co

m.touloupi@greenerthangreen.co

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

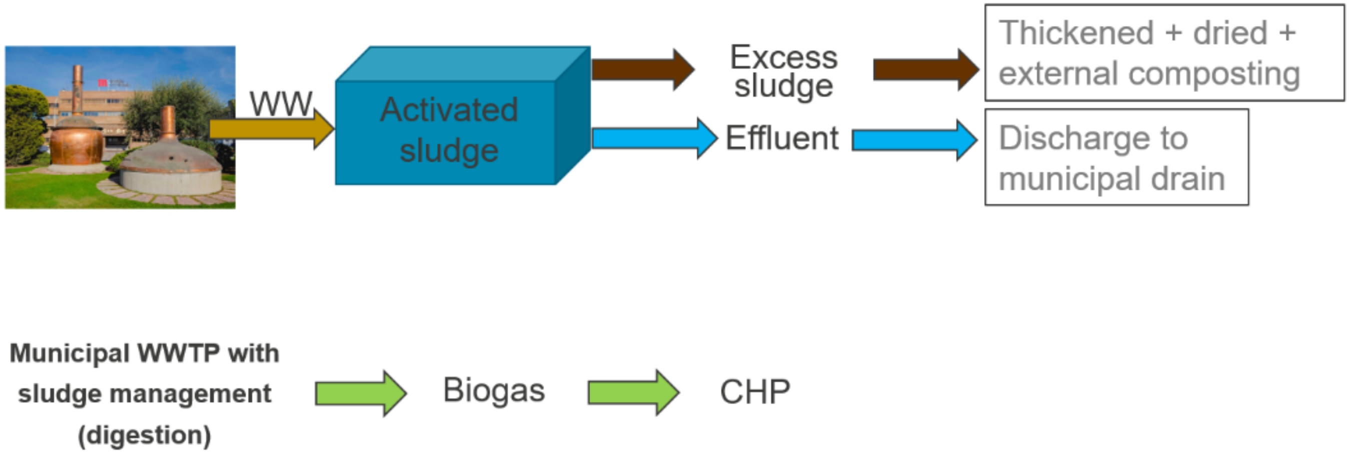
2.5. CS5: Lleida

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
5	1.2.5	Monitoring system for fouling in AnMBR	No pilot plant --> excluded from D1.2			
		(NF + RO) + (AOP + UV)	100%	100%	100%	Jan./Jun. 22
	1.3.2	AnMBR	100%	100%	100%	Dec. 22
		Pilot ELSAR	100%	100%	100%	Dec.22
		Full-scale ELSAR		50%	0%	Sep 23
		SOFC		100%	100%	Dec. 22
	1.4.4	Concept study: recovery of nutrients	No pilot plant --> excluded from D1.2			
		Solar-driven hydrothermal carbonisation demo plant	100%	100%	100%	May 22

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

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

CS5: Situation before Ultimate



3

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

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

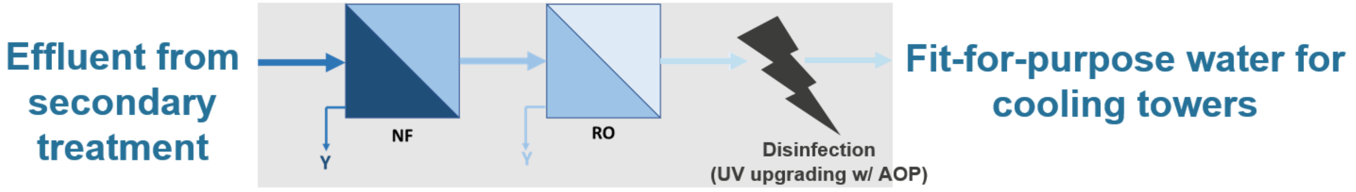
The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318

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



TRL: 7 → 9

Capacity: 50 m³/d

Quantifiable target: 4200-4600 m³/a for cooling towers; 10-15% reduction of freshwater via reuse of treated water

Status/progress:

- Detailed design completed
- UF & RO: operational
- AOP & UV: operational

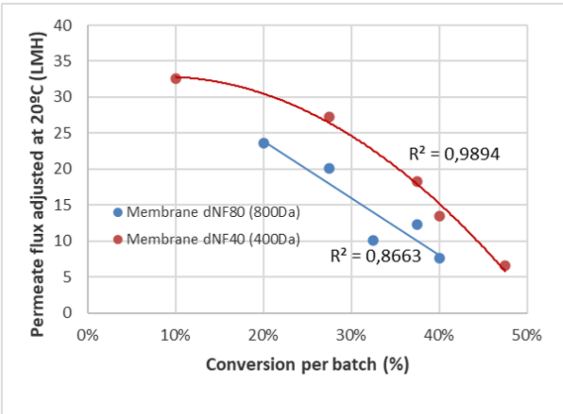
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

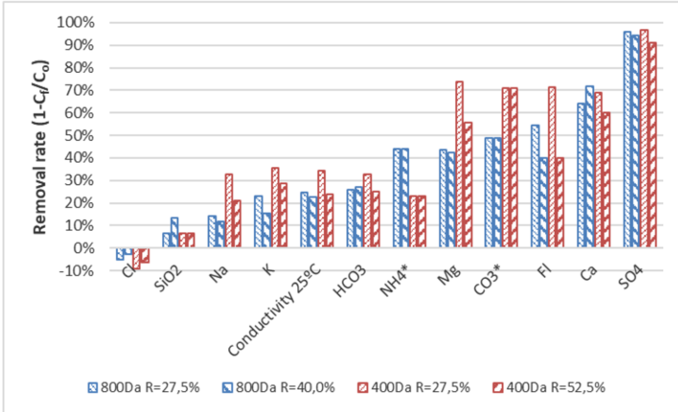
CS5: Results of laboratory experiments

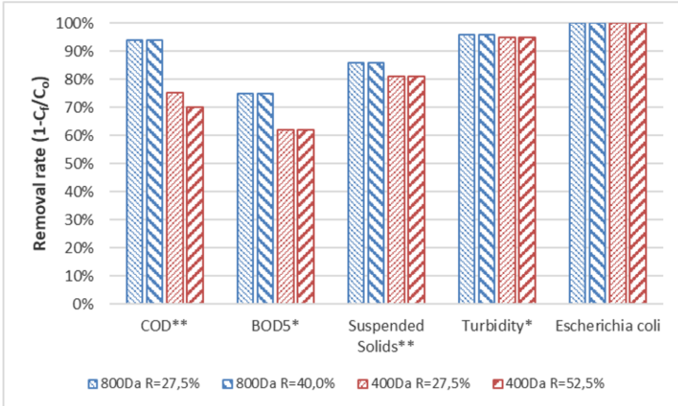
Subtask: **1.2.5 Reuse of brewery wastewater as process water**

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.







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

6

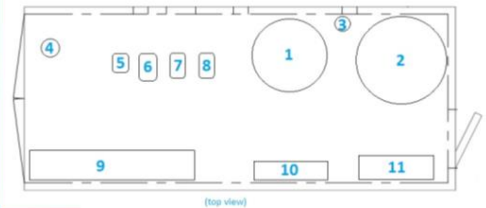
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

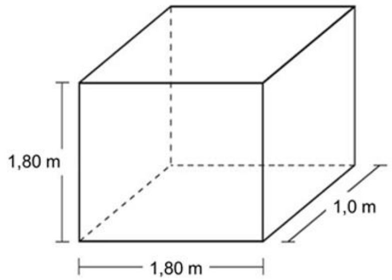


Dimensions:
6,0m x 2,4m x 2,4m

Reverse osmosis demo plant (1st trials)

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

Dimensions:



7

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

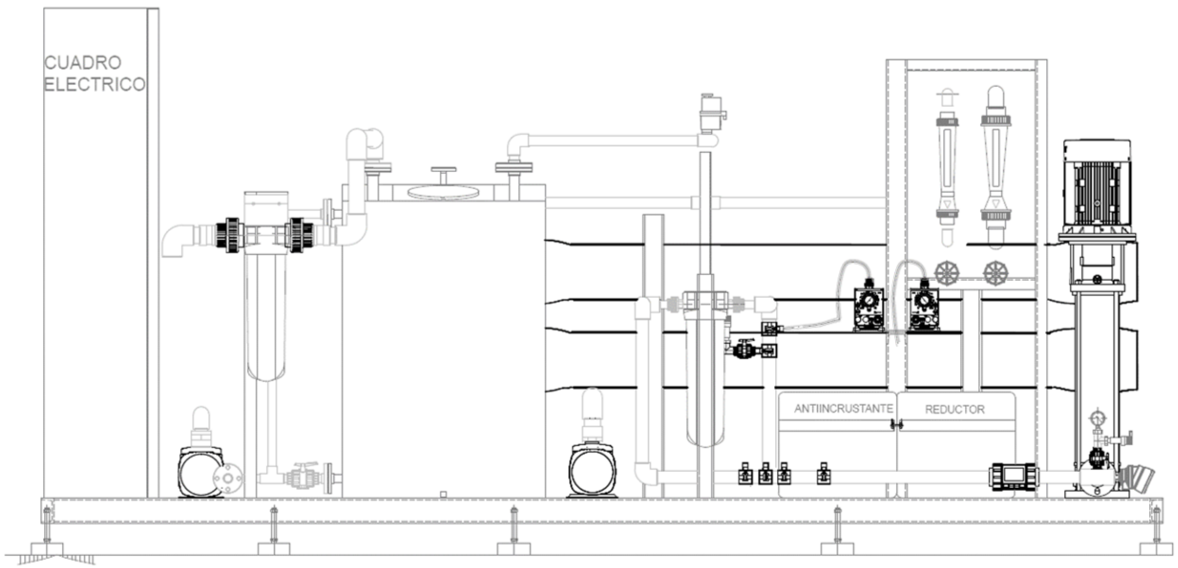
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS5: Pictures of NF & RO pilot system

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

Reverse osmosis demo plant (2nd trials)

Due to water production limitations, a second larger demo-scale RO plant has been operated in Ultimate



Composed by:

- Electrical cabinet
- 1 buffer tank
- 2 RO spiral membranes
- 1 feeding pump
- 1 low-pressure pump
- 1 high-pressure pump
- 1 fabric filter
- 2 dosing pumps and tanks for dosing anti-scaling and disinfectant
- Continuous monitoirng of conductivity, pH, flow
- Several rotameters and manometers

Dimensions:

- LxWxH: 4,5m x 1,4m x 2,1m

8

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

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

CS5: Pictures of NF & RO pilot system

Subtask: 1.2.5 Reuse of brewery wastewater as process water

Nanofiltration demo plant

Reverse osmosis demo plant

9

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

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

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 or BLENDED REGENERATED WATER	
	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

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

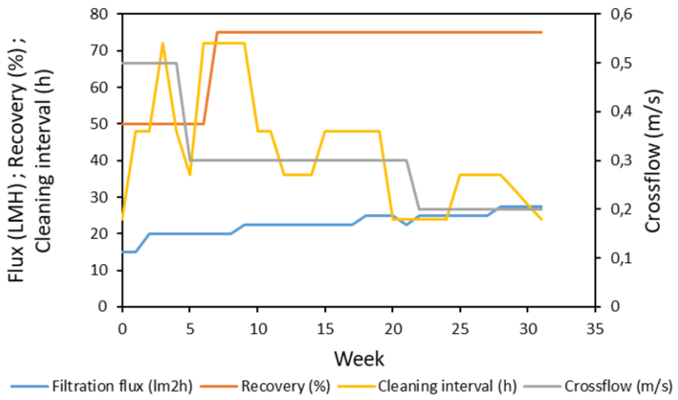
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS5: Operational procedures and methodologies

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

Method for nanofiltration: change of operating conditions, by means of intensification of the filtration process.
Variable conditions:

- Flux
- Recovery
- Cleaning interval (frequency)
- Crossflow velocity



Method for reverse osmosis: stable conditions, although trying to maximize the recovery and the produced flow by means of pumping adjustment. Influence of dissolved COD on cleaning membranes. Simulation of RO through software.

11

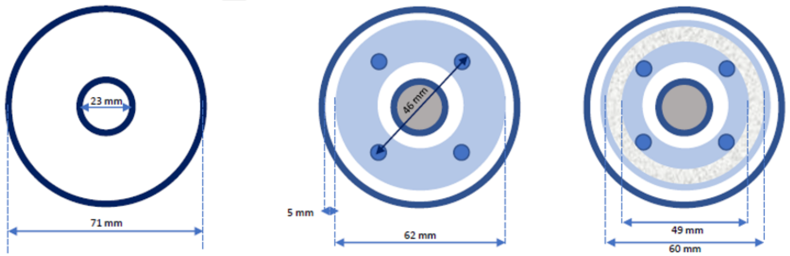
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

CS5: Development of AOP & UV test device

Subtask: 1.2.5 Reuse of brewery wastewater as process water

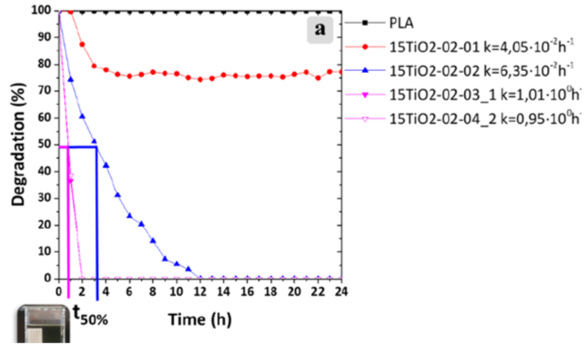
1. Photocatalytic reactor with support and first PLA prototypes adapted to the geometry of existing UV lamp.



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

12

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

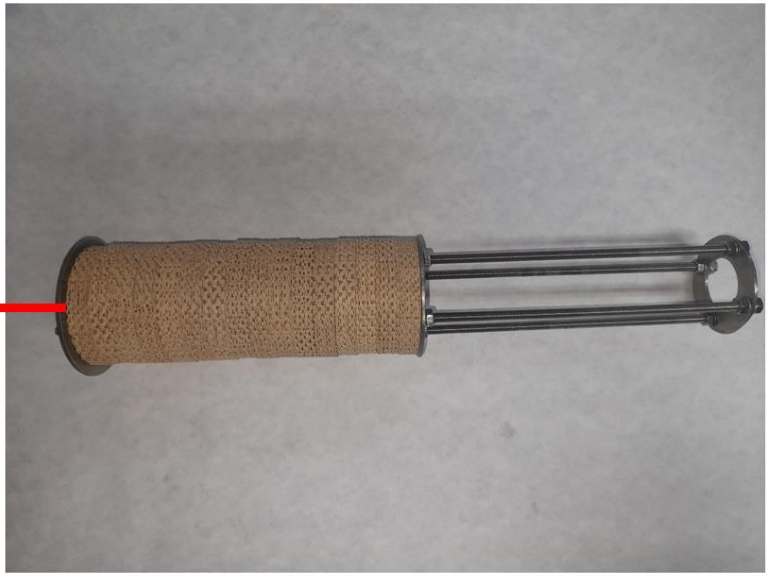
3. Batch tests monitoring ofloxacin degradation with synthetic and real water.

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

CS5: Pictures of AOP & UV test device

Subtask: 1.2.5 Reuse of brewery wastewater as process water

Pump and structure with filaments



13

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

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

CS5: Operational procedures and methodologies

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

Analytical plan

Determination of Ofloxacin (a quinolone antibiotic, $C_{18}H_{20}FN_3O_4$) concentration and UV absorbance in batch tests:

- Per triplicate
- Determination of the influence of support and support + membranes on results, compared with only UV activity.

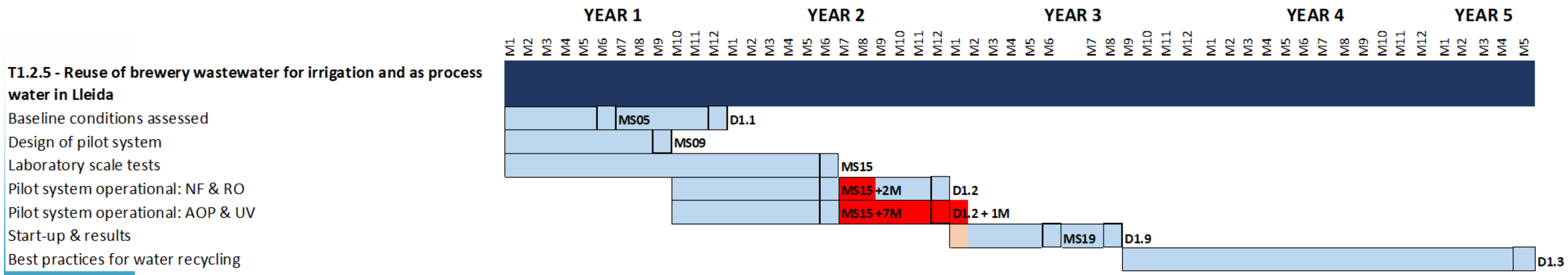
	Support	Membrane	Presence of TiO_2
Experiments 1&2	N	N	N
Experiments 3&4	Y	N	N
Experiments 5&6	Y	Y	N
Experiments 7&8	Y	Y	Y
Experiments 9&10	Y	Y	Y
Experiments 11&12	Y	Y	Y

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

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

CS5: Subtask 1.2.5 – Timeline

Subtask: 1.2.5 Reuse of brewery wastewater as process water



→ **NF & RO are operational**

→ **AOP & UV are operational**

Legend

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

15

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

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

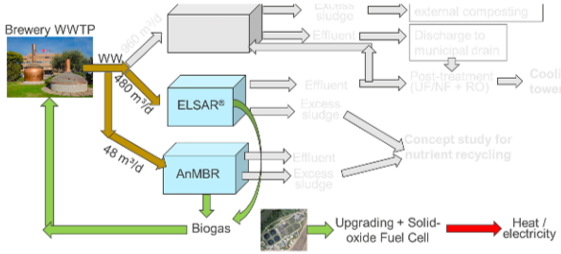
CS5: Subtask 1.3.2 Status/progress

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 (full-scale ELSAR); 6 m³/d (pilot-scale 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.
- Operational: AnMBR, SOFC, pilot-scale ELSAR
- Building license received: full-scale ELSAR; construction expected to be completed in Sept. 2023

16

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

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

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.

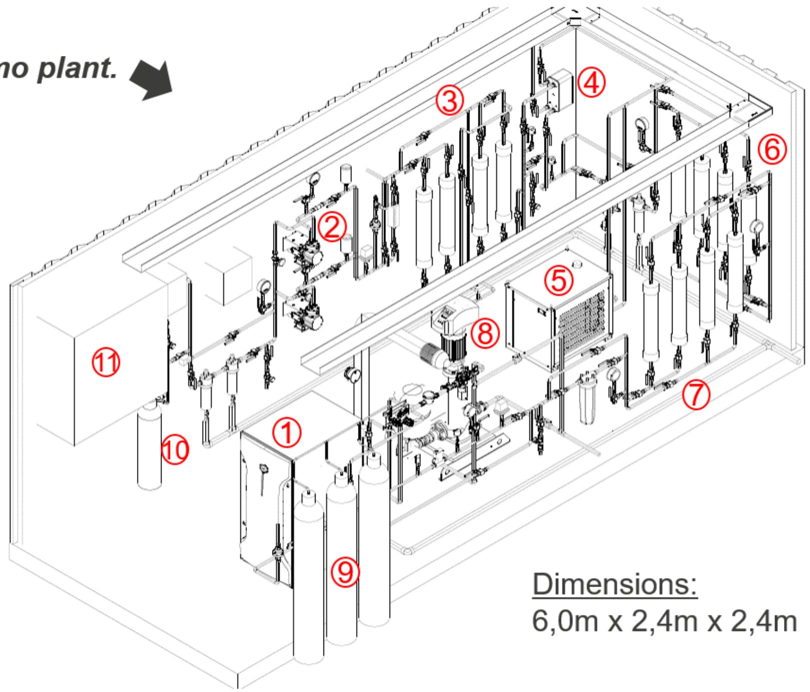
Suplier Solid Power; Model BlueGen BG-15.

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

17

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

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

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

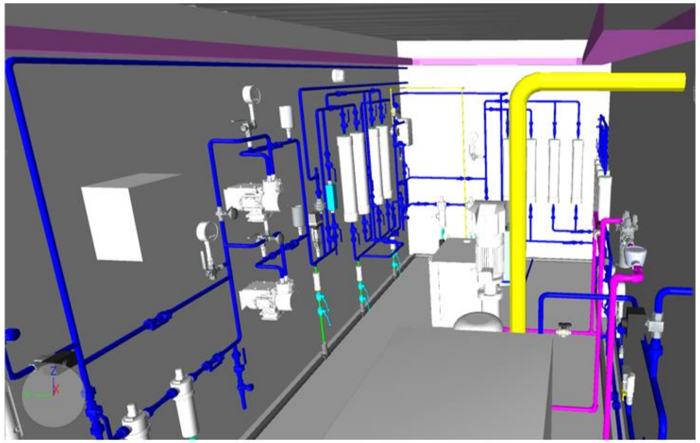
18

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

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

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)

In November 2022:
1. Final integration of fuel cell
2. Hot start-up (biogas) → Operation

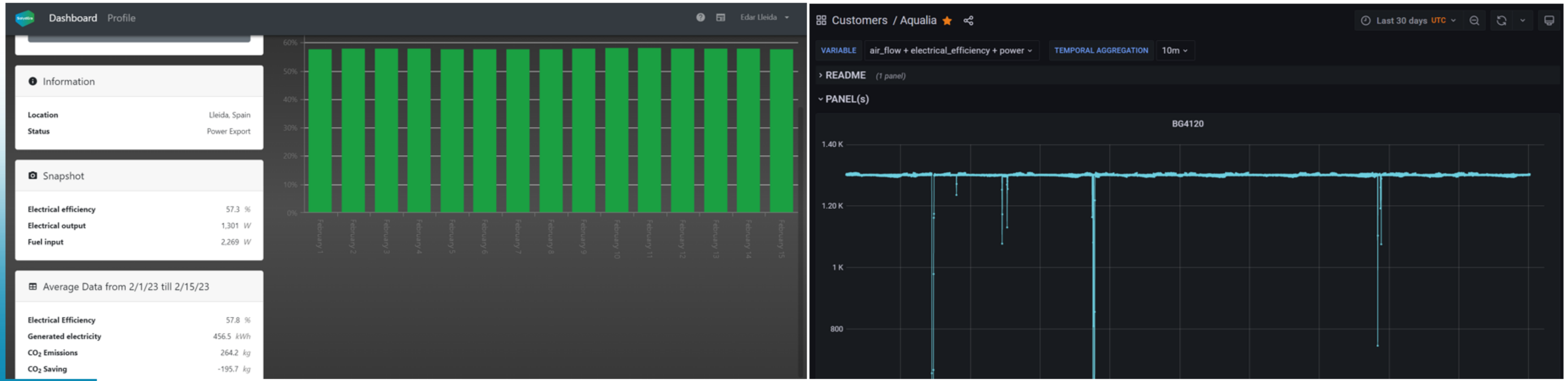
19

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

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

CS5: Pictures of the new technologies

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



→ First 2 months of operation show a constant and expected output's behaviour:

- → Constant electrical efficiency between 57,5- 57,9%
- → Produced power 1,3 kW
- → Slight adjustments for optimization are to be done: automatization, measuring, etc.

20

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

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

CS5: First results

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

On 01.12, the first characterization of the biogas in WWTP Lleida was carried out before and after being subjected to the pre-treatment (iron salts + zeolites + activated carbon), in order to verify the performance of the proposed pre-treatment. The main results are:

- Moisture removal from 10,800 ppm to 5,000 ppm.
- No presence of siloxanes (<0.05 mg / Nm^3) neither in input nor in pre-treated biogas.
- Total removal of H2S (80.3 mg/Nm^3 inlet)
- Presence of ammonia, with slight concentration increase (from 8.8 to 11.4 mg / Nm^3)
- No presence of VOC in the input (<0.02 mg / Nm^3), but surprisingly a small concentration in pre-treated biogas (1 mg / Nm^3).

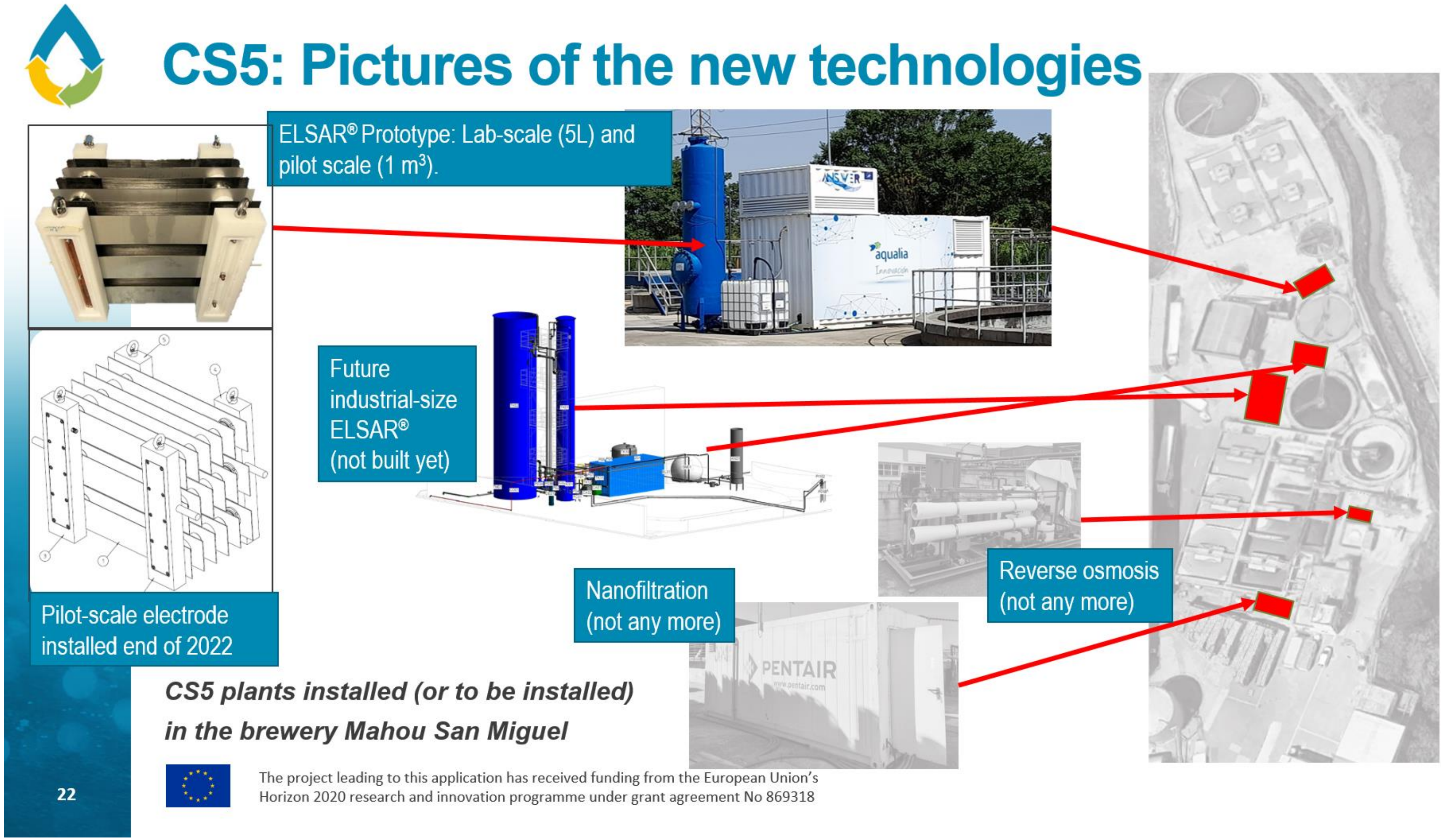
Further analyitcal determination is going to be done in 2023.

→ **Pre-treatment of biogas before entering the SOFC is validated.**

21

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

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



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

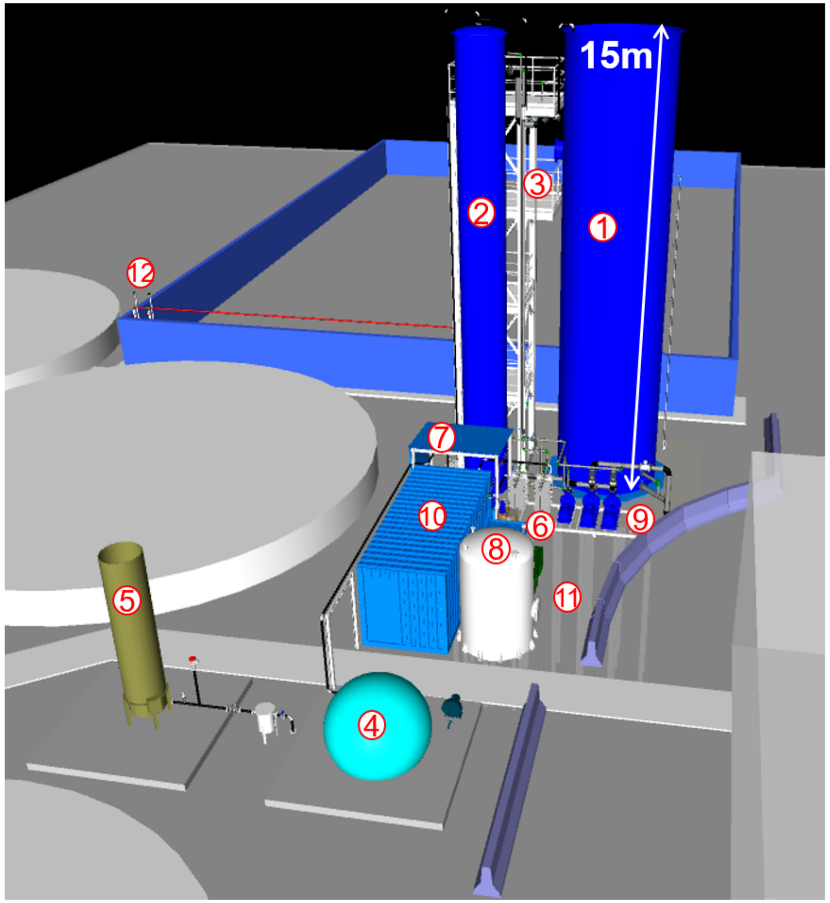
CS5: Pictures of the new technologies

Subtask: Electrostimulated anaerobic reactor (ELSAR®)

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



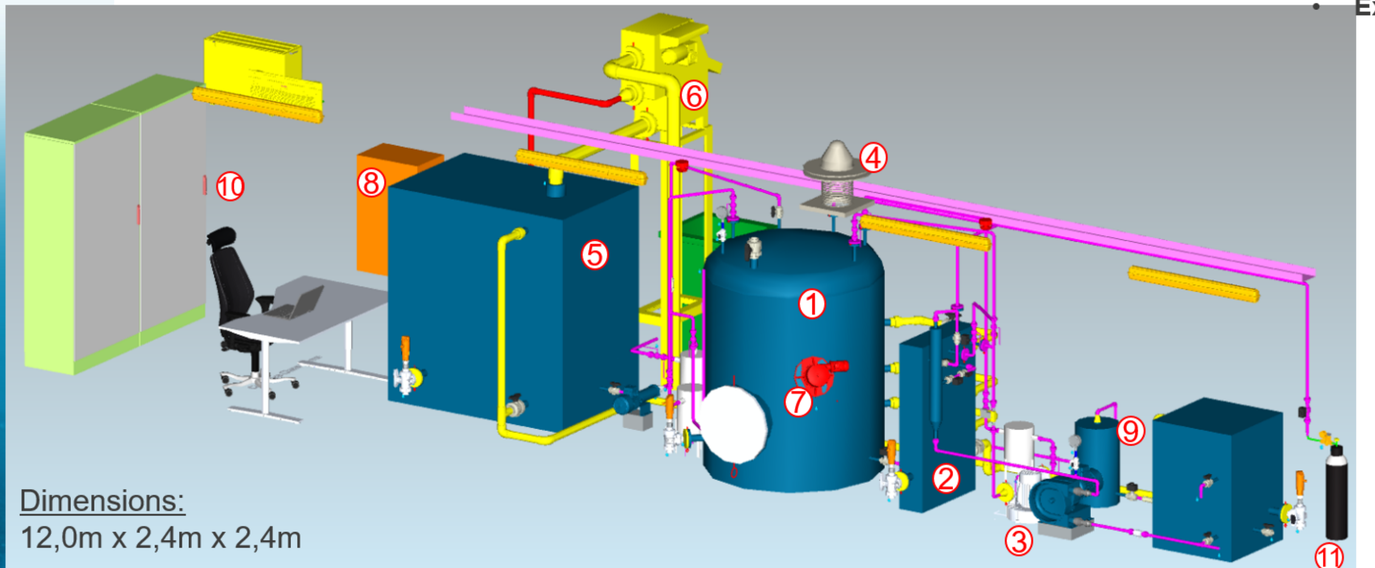
23

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

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

CS5: Picture of the AnMBR

Subtask: Anaerobic Membrane Bio Reactor (AnMBR)



Dimensions:
12,0m x 2,4m x 2,4m

- **Capacity**
  - *Input Industrial Wastewater*
  - *Flow 2 m³/h*
  - *OLR 200 kg COD/d*
- **Reactor features**
  - *Total Volume Reactor 40m³*
  - *Mesophilic range (30 - 37°C)*
- **Expected results**
  - *95% COD removal*
  - *3,5 Nm³ 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

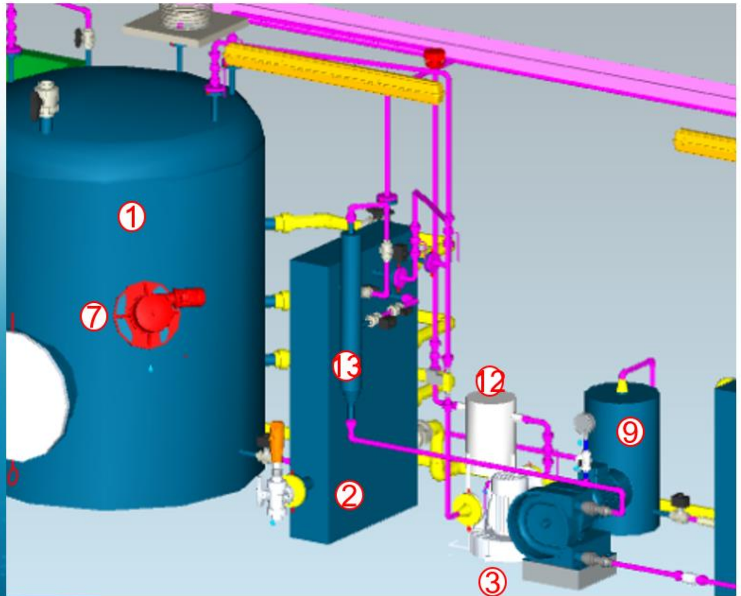
24

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

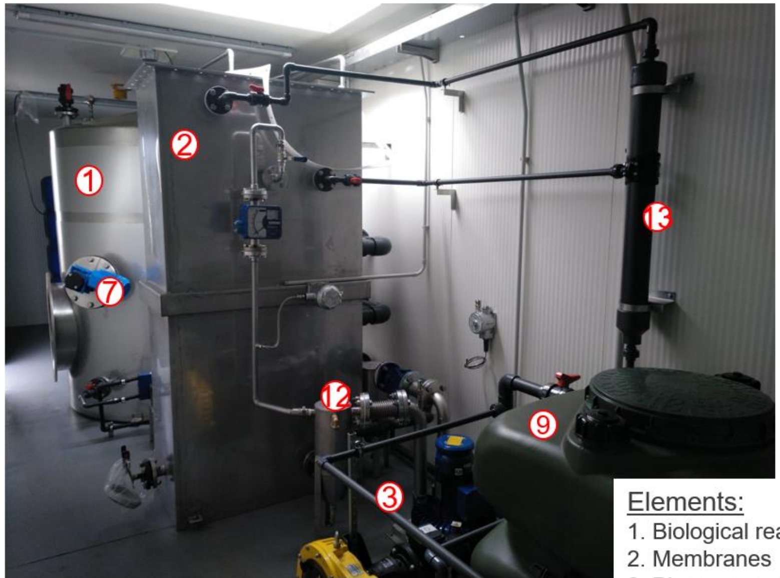
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

25

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

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

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

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

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

CS5: Operational procedures and methodologies

Subtask: **ElectroStimulated Anaerobic Reactor (ELSAR®) and Anaerobic Membrane Bio Reactor (AnMBR)**

Due to postponement of building permission obtention (12 months waiting time, instead of max. 5 months), the following measures have been taken:

- Extension of lab- and pilot-scale experiments to accelerate start-up and optimization phases of full-scale ELSAR®

Picture of the pilot plant in WWTP Mahou SM.
Average results in February 2023 (tests without ElectroQ).

Conditions		Results	
Parameter	**Value**	**Parameter**	**Value**
Temperature	36,3ºC	TCOD removal	89,9%
pH	8,93	TSS removal	43,8%
ORP	-73mV	Methane productivity	0,38 m³ CH_4/kg removed COD
OLR	3,6 kg COD/m³/d		

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

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

CS5: Operational procedures and methodologies

Subtask: **ElectroStimulated Anaerobic Reactor (ELSAR®) and Anaerobic Membrane Bio Reactor (AnMBR)**

The inoculation of anaerobic sludge was made in Dec. 2022. So far it has been fed in batch mode, feeding small volumes of municipal wastewater, without (ultra)filtering. After consolidating the biomass, starting March 2023 the filtration will be activated.

From left to right:

- ***Manhole for wastewater suction***
- ***Level of digester***
- ***Gas counter***
- ***Control panel***

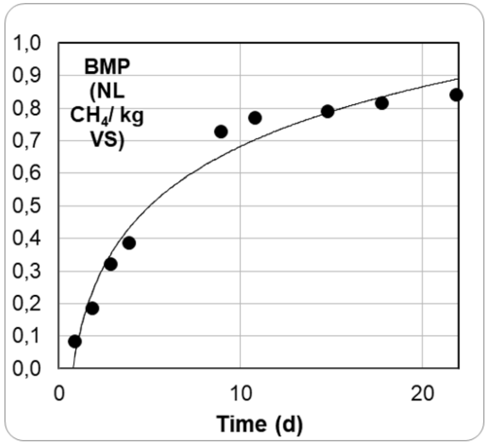
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

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 certain 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

29

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

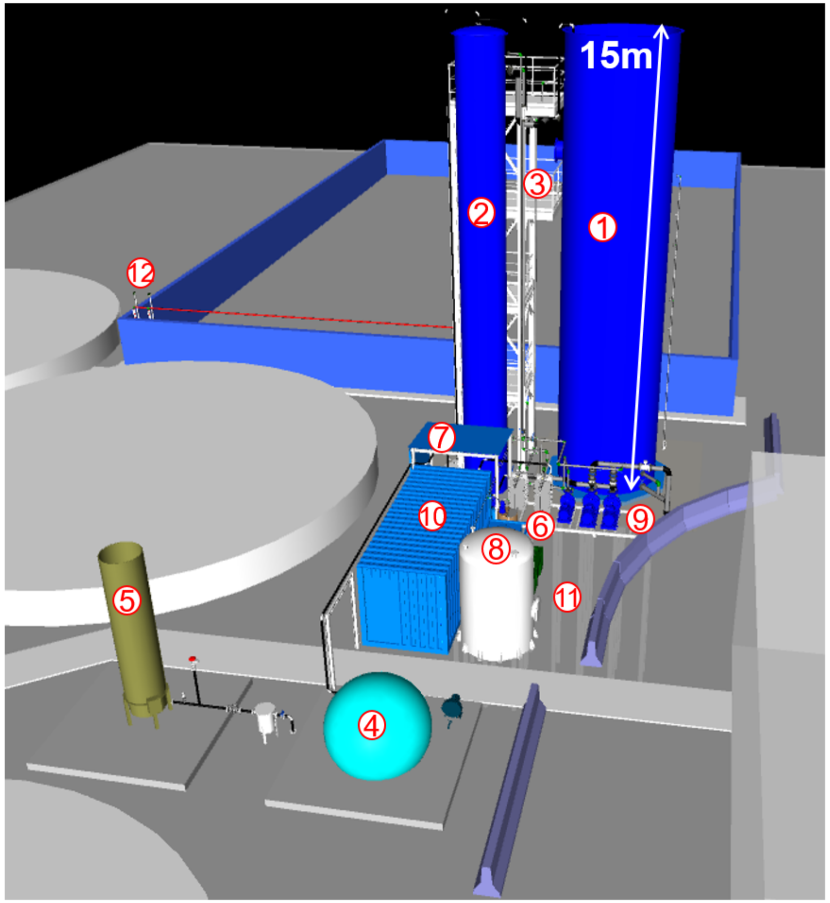
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS5: full-scale ELSAR

Subtask: **Electrostimulated anaerobic reactor (ELSAR®)**

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



30

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

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

CS5: Pictures of full-scale ELSAR construction

Subtask: **Electrostimulated anaerobic reactor (ELSAR®)**

Drawing of the micropiles below the ELSAR and the buffer tank (left). Building of micropiles (right).

- Due to the height of the reactor, there is a need of deep civil works (micropiles)

31

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

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

CS5: Pictures of full-scale ELSAR construction

Subtask: Electrostimulated anaerobic reactor (ELSAR®)

Pumps before mechanical assembly.

The retaining wall for emergency NaOH leakages.

Flare being installed.

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

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

CS5: Full-scale ELSAR

Concrete platforms for torch, gasometer and lamellar clarifier

- Civil works expected to finish in June 2023
- New additional structures were required: lamellar clarifier, retaining wall for emergency NaOH leakages
- Most of the electromechanical components are on site
- Mechanical and electrical assembling currently being done

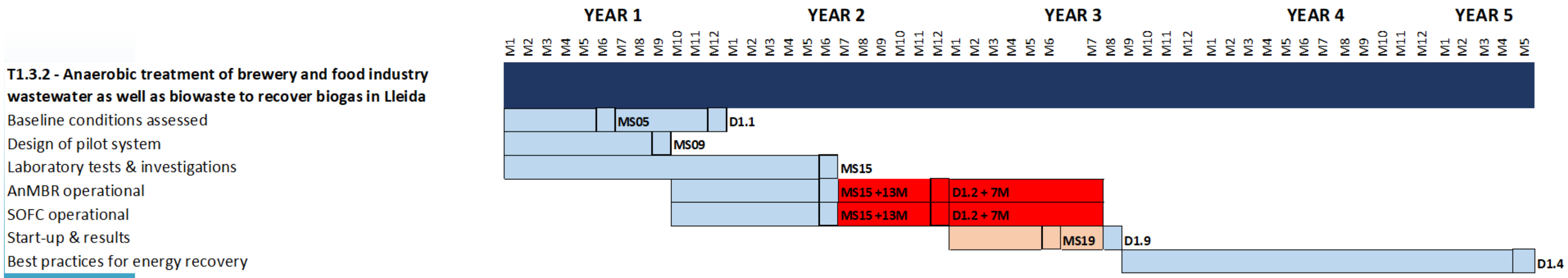
Buffer tank (left) and reactor (right).
On the bottom left the retaining wall for emergency NaOH leakages can be seen

33

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

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 are operational since Dec. 2022**

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

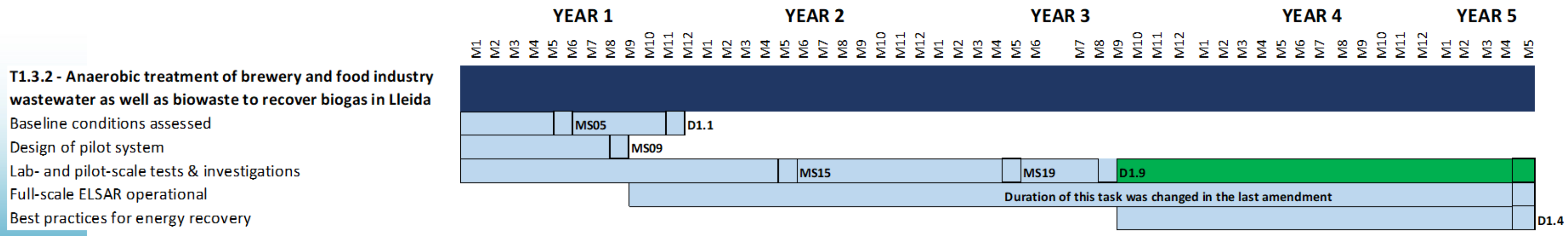
34

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

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

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



ESLAR (pilot-scale) is operational since Dec. 2022

ELSAR (full-scale) expected to be operational in Sept. 2023 (M40)

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

→ Optimization phase of full-scale ELSAR is not part of the DoA anymore (since Jan. 2023)

Legend

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

35

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

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

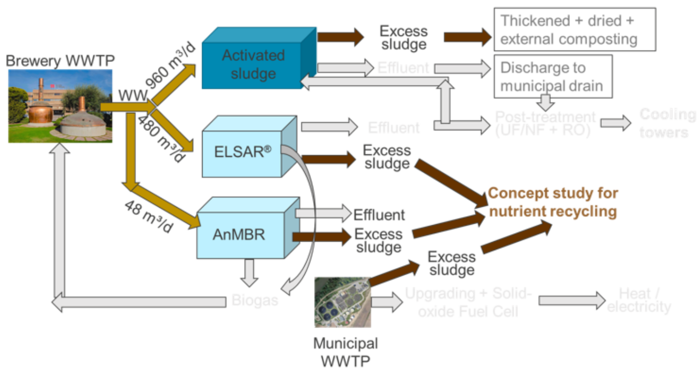
CS5: Subtask 1.4.4 Status/progress

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

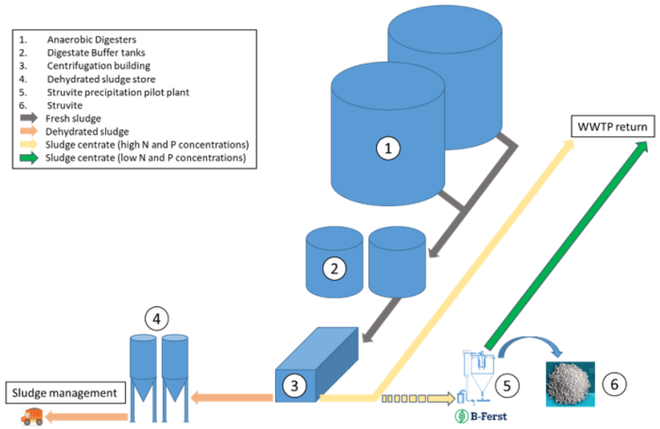
Status/progress: Feasibility report under progress.

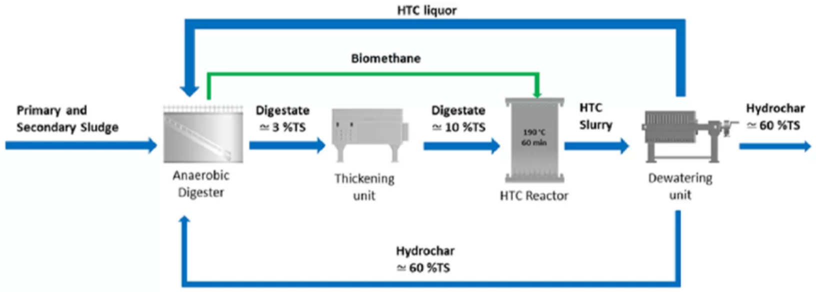
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

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

37

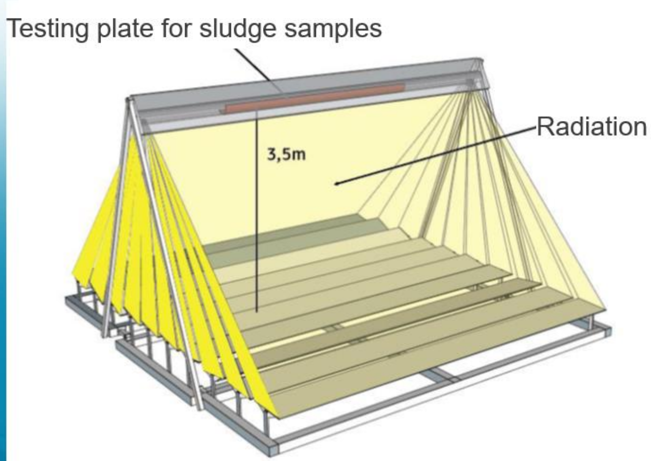
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

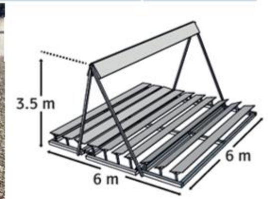
CS5: Pictures of the solar pilot plant

Subtask: **1.4.4 Recovery of nutrients from brewery digestates**

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



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

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

38

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

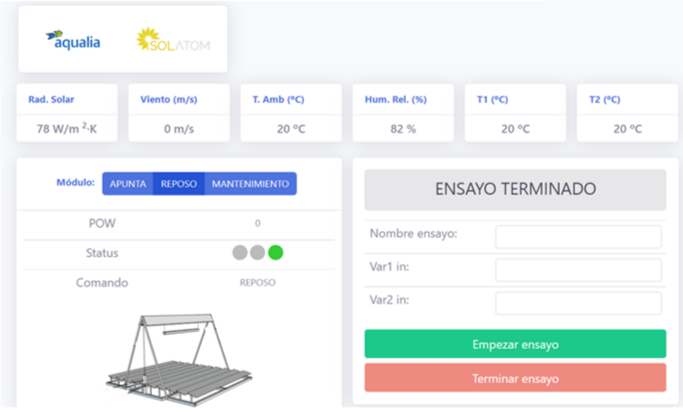
CS5: Operational procedures and methodologies

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), contrasting with EC draft.
- **Evaluation of results:**
  - Monitored variables at different set temperatures will be contrasted with models
- **Mode:**
  - Batch tests → proof of concept
  - Development & test of a continuous system

Example of screen of the remote visualization



	E. coli	***Salmonella***	***Clostridium***
	CFU/g DM	Presence in 50g	(CFU/g DM)
Draft EU 86/278/CEE	**$< 10^3$**	**NO**	**$< 3 \cdot 10^3$**

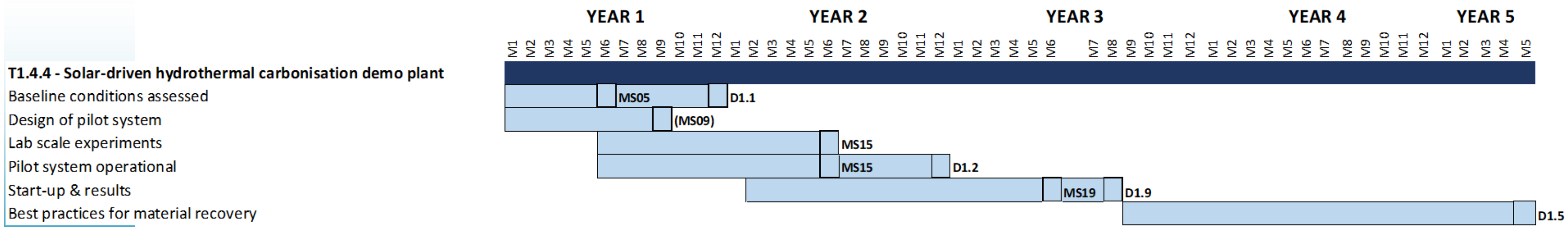
39

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

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

CS5: Subtask 1.4.4 – in time

Subtask: **1.4.4 Recovery of nutrients from brewery digestates**



→ **Solar pilot plant is operational since May 2022**

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

40

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

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS5 Contact

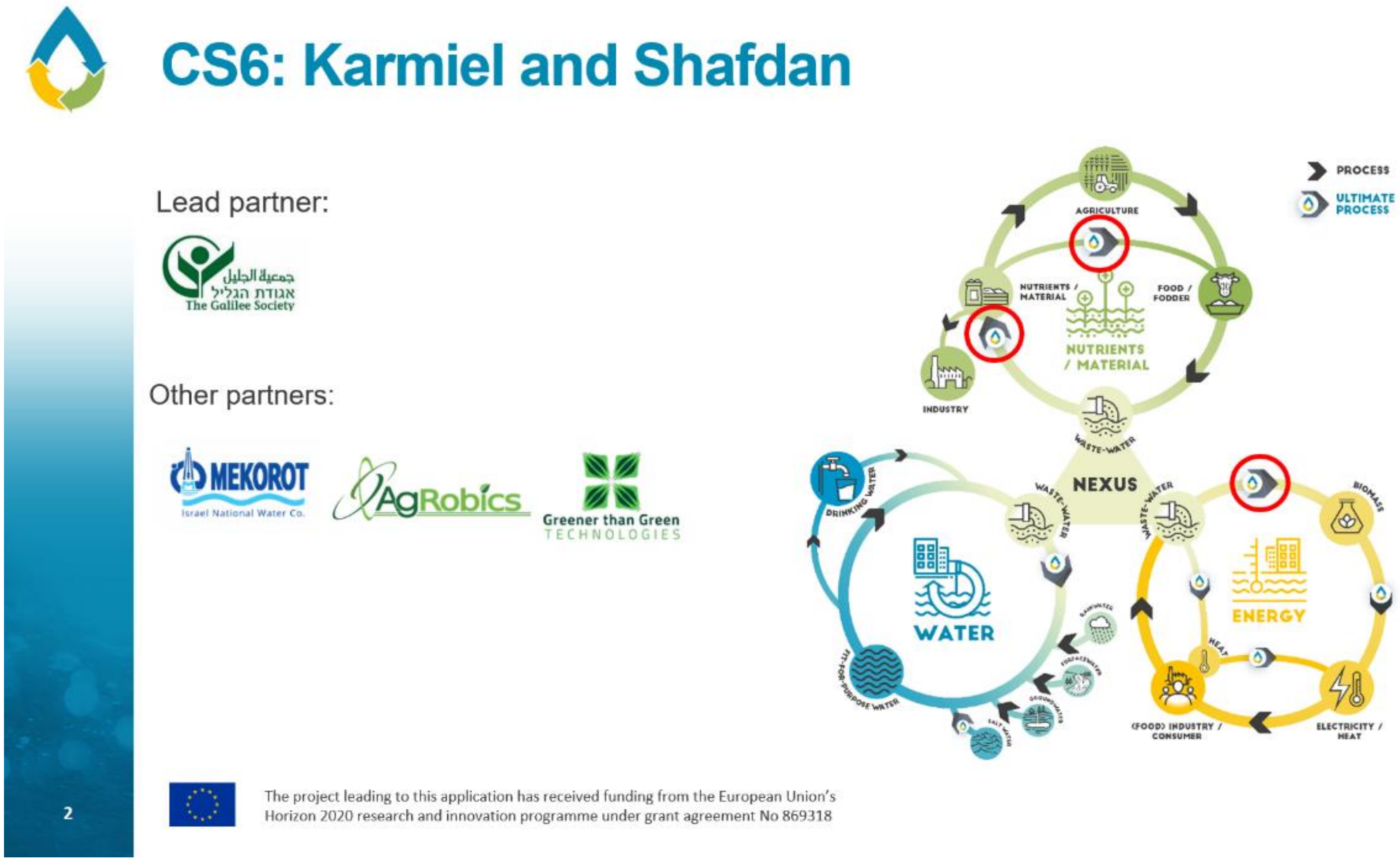
antonio.gimenez@fcc.es

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

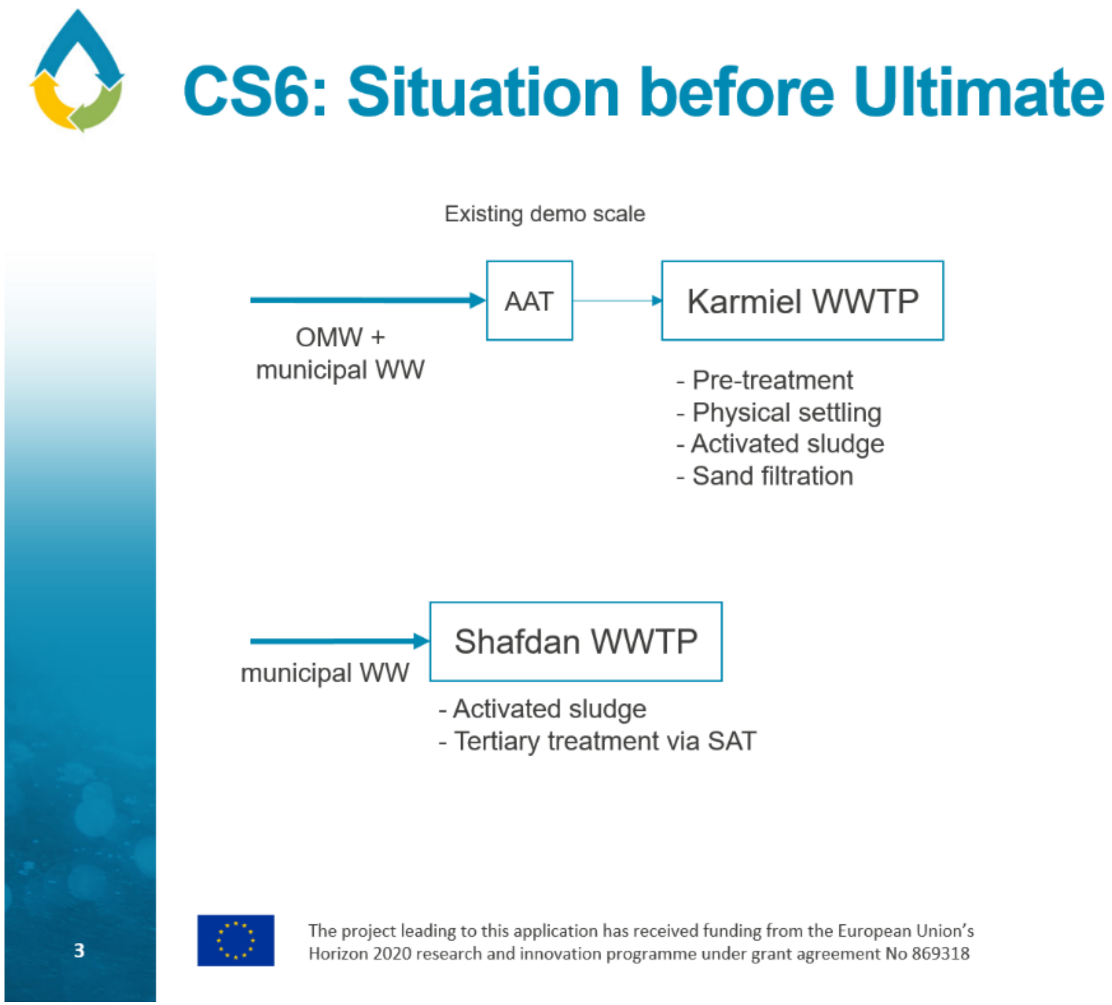
2.6. CS6: Karmiel & Shafdan

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
6	1.3.3	AAT Karmiel		100%	100%	May 22
	1.3.4	AAT + membrane filtration incl. PAC Shafdan	90%	100%	100%	Aug 22
	1.4.5	Recovery polyphenols (pilot system: adsorption column)	100%	100%	100%	Dec. 22

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

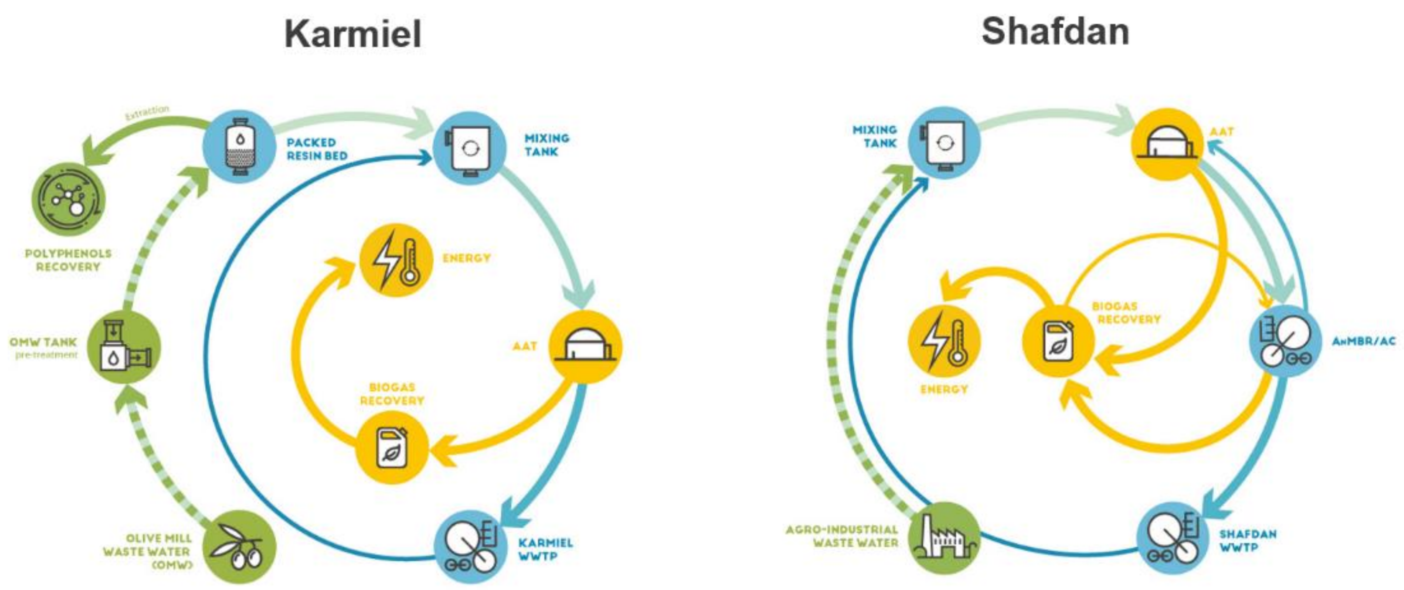


The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318



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

CS6: Objectives of the Ultimate solutions



4

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

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

CS6: Subtask 1.3.3 Status/progress - Karmiel

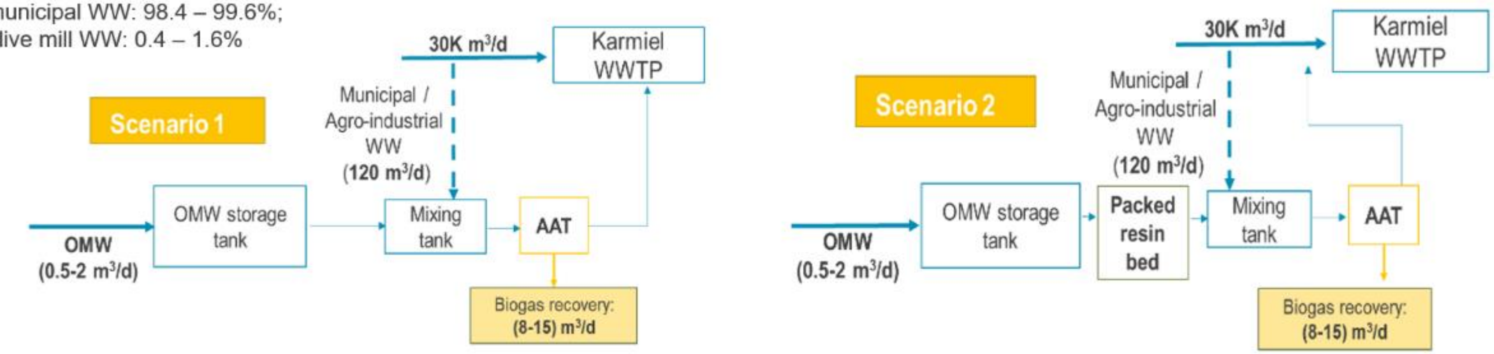
Subtask: 1.3.3 Biogas production from anaerobic pre-treatment of municipal and/or industrial wastewater in Karmiel

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%



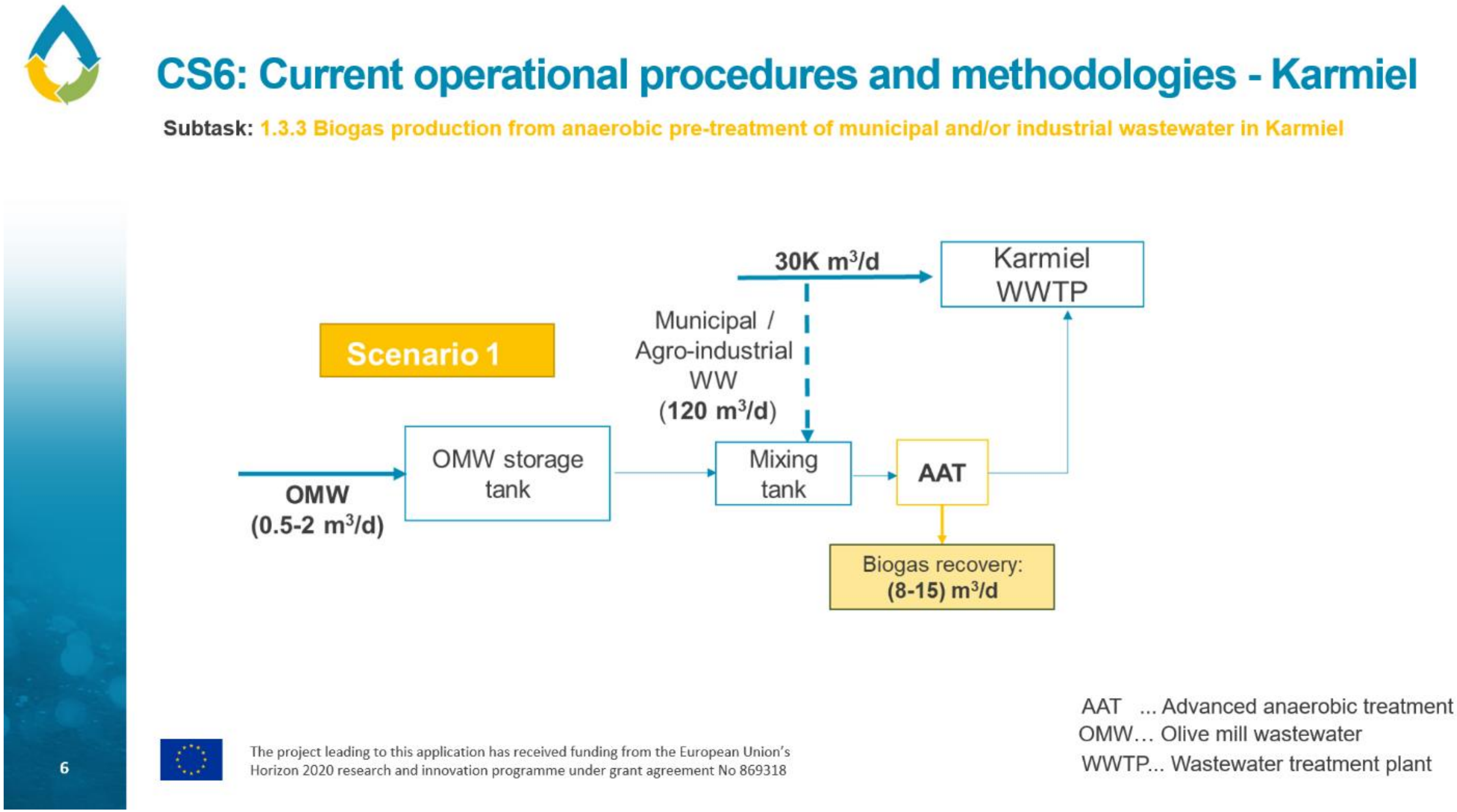
Quantifiable targets: 8-15 m³ biogas/d; 20-25% reduction of energy demand; 25% energy recovery

Status/progress:

- detailed design completed
- constructed and operational

5

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



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

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

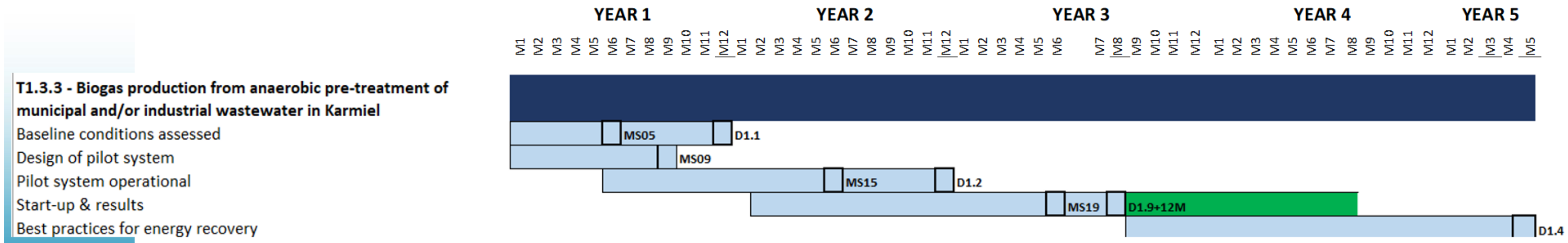
7

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

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

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



→ **Immobilized anaerobic high-rate reactor (AAT) is operational**

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

8

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

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

CS6: Subtask 1.3.4 Status/progress - Shafdan

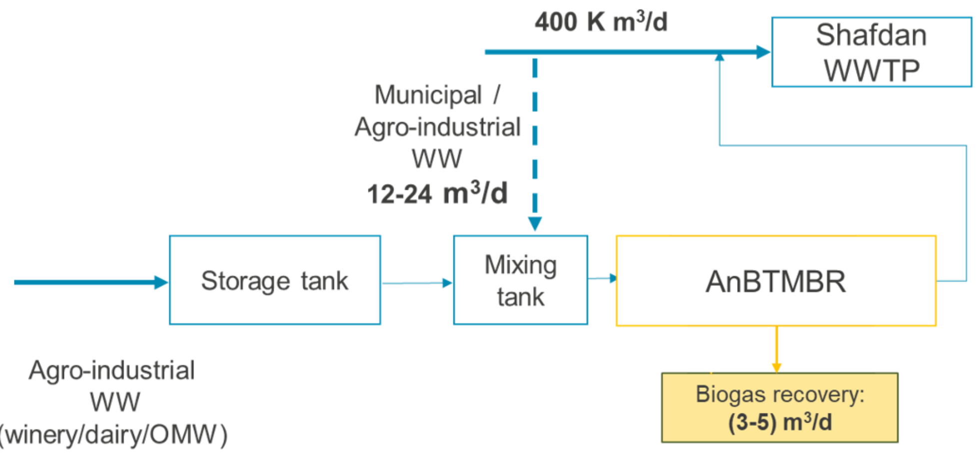
Subtask: 1.3.4 Combining anaerobic biofilm treatment with membrane filtration and activated carbon in Shafdan

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
- Constructed and operational

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

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

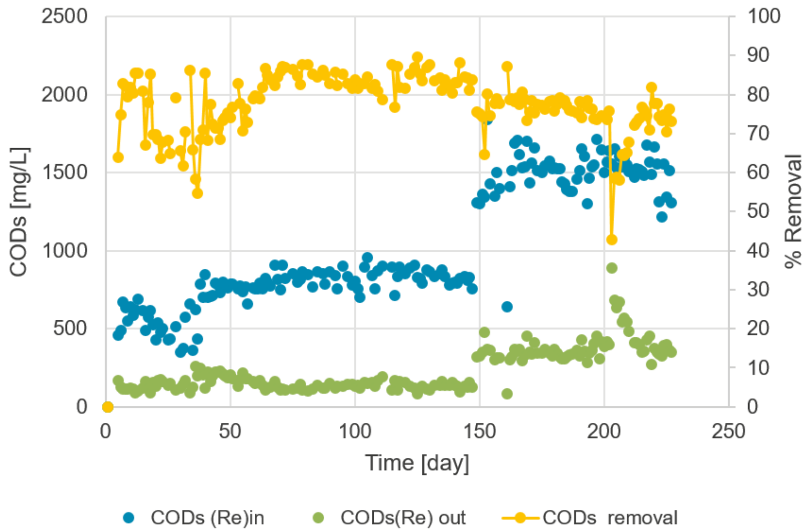
9

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

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. Below you can see the picture of the lab-scale system with results of the soluble COD removal by the lab scale AAT.



10

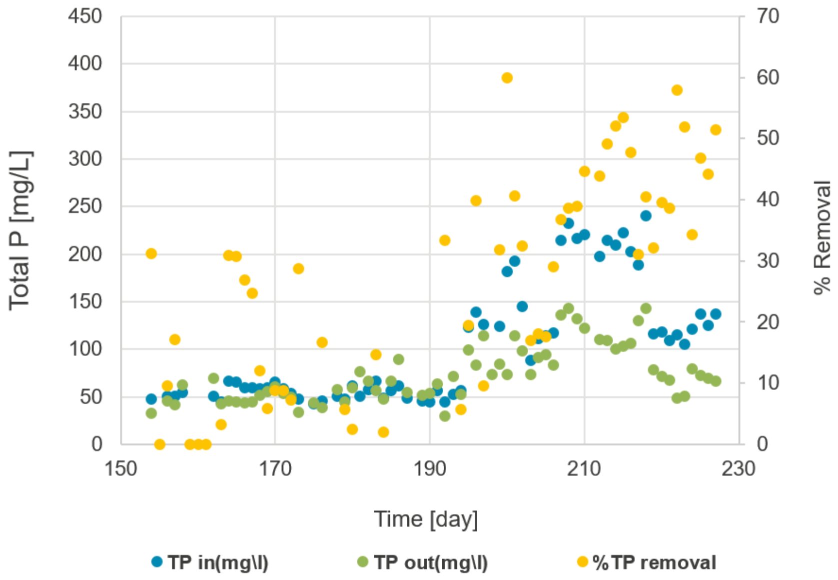
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

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. Below you can see the picture of the lab-scale system with results of the total phenolic content removal by the lab scale AAT.



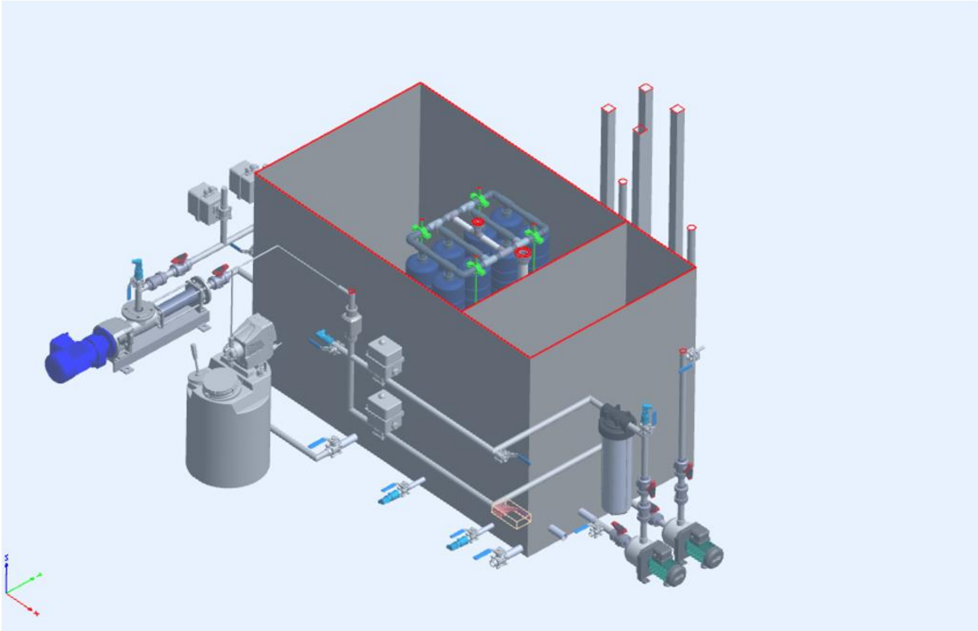
11

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

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

CS6: Pictures of the anaerobic biofilm treatment membrane bioreactor system

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



12

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

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

CS6: Pictures of the anaerobic biofilm treatment membrane bioreactor system

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

13

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

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

CS6: Pictures of the anaerobic biofilm treatment membrane bioreactor system

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

14

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

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

CS6 Video: construction of the anaerobic biofilm treatment membrane bioreactor system

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

This video is accessible via the indicated link below this presentation on the ULTIMATE webpage.

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

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

CS6: Pictures of the anaerobic biofilm treatment membrane bioreactor system

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

16

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

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

CS6: Pictures of the anaerobic biofilm treatment membrane bioreactor system

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

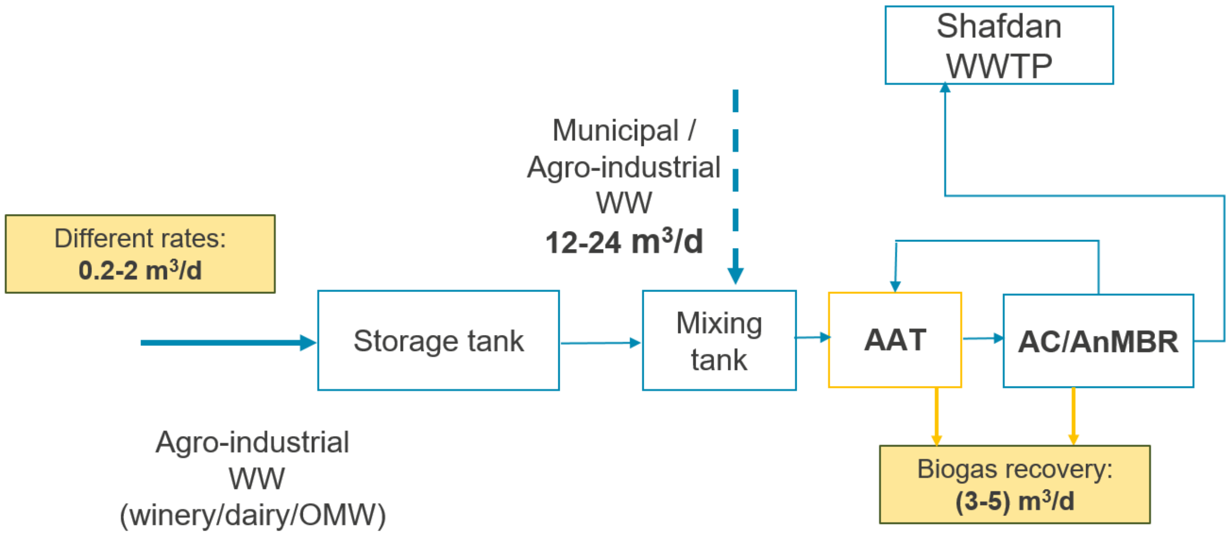
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

17

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

CS6: Operational procedures and methodologies Shafdan

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



18

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

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

Start-up process of the Shafdan system

- After connecting the system with the inlet of wastewater (after filtration), the AAT system was started on August 2022 in order to reach a steady state of the anerobic unit (fixed foam-based AAT system) before connecting it to the filtration (Membrane unit). From August-October, 2022
- The filtration system (membrane) was mechanically and electrically commissioned, a deep check of the sensors and valve was done. Many issues related to the sensors, electrical panel and control system took about a month to be solved with the support of SFC staff (until end of September 2022)
- The membrane unites were checked with tap water with the support of the engineer of SFC Umwelttechnik GmbH (provider of the AnMBR system), where the connections and membrane.
- After then, the membrane system was connected to the outlet of the AAT system (on November 7th, 2022) and first complete run was started with 0.5 m^3/h. From this time until November 16th, an intensive training on the automatic operation/monitoring was given by the SFC staff to the technical team of GS/Agrobic/Mekorot.
- On Nov. 21st 2022, we started the sampling camping according to the sampling plan.

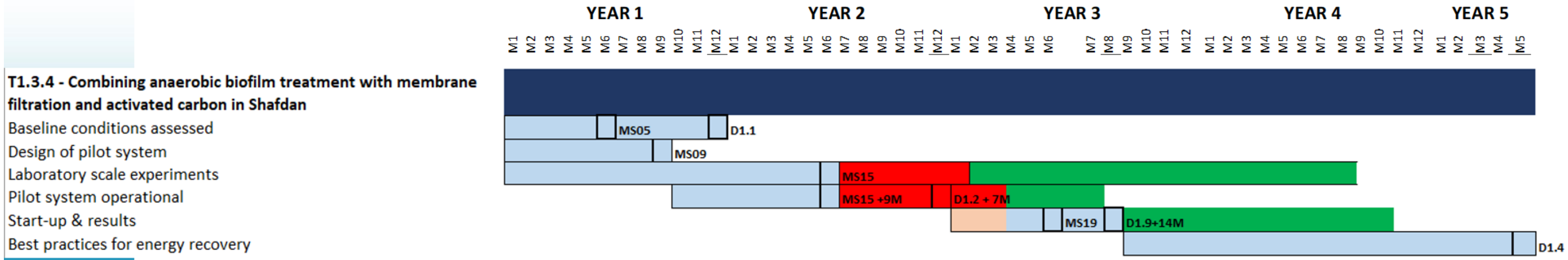
19

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

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

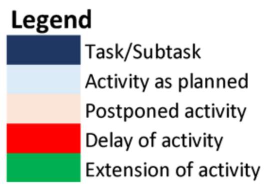
CS6: Task 1.3.4 - Timeline - Shafdan

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



→ **AnTBMBR is operational since August 2022**

→ Start-up was successful
→ Sampling started in December 2022



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

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

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

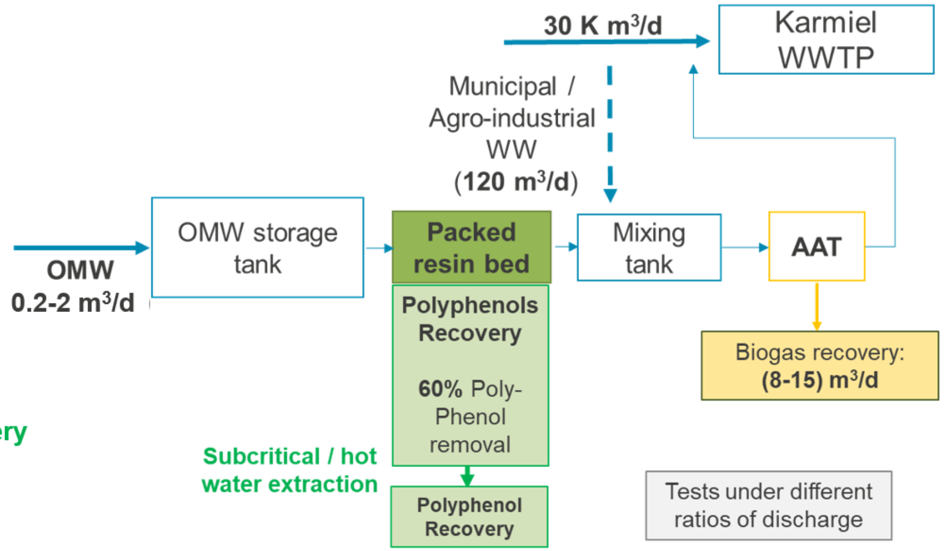
Ultimate solution to foster circular economy:
Adsorption column with packed resin bed and extraction with pressurized hot water

TRL: 5 → 7

Capacity: 0.2-2 m³/d

Quantifiable targets: > 40% Polyphenols recovery

Status/progress:
- Pilot plant operational
- Lab scale experiments completed



21

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

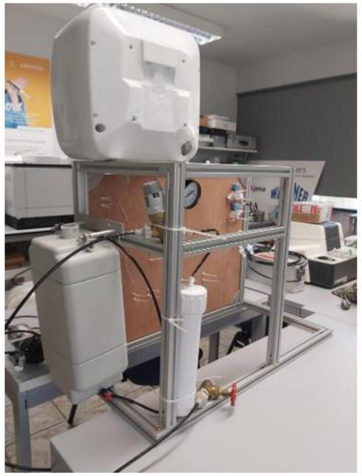
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS6: Pictures of the new technologies

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

Lab scale – Dynamic adsorption

Static adsorption



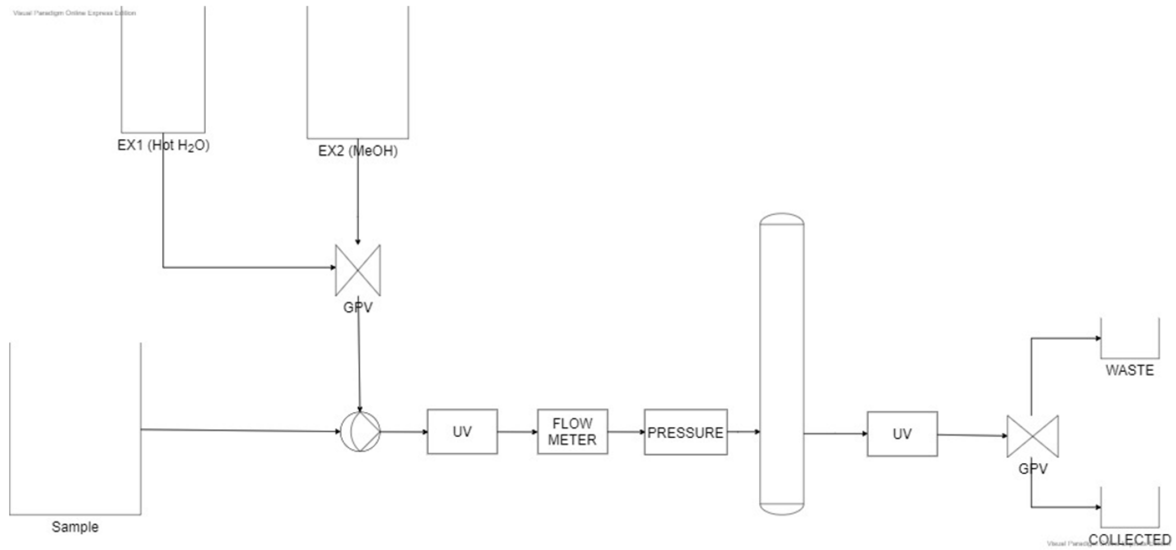
22

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

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

CS6: Operational procedures and methodologies

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



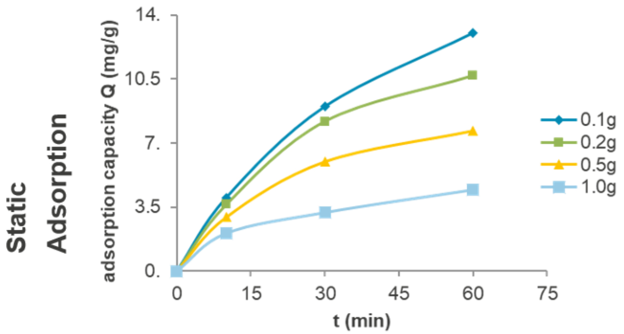
23

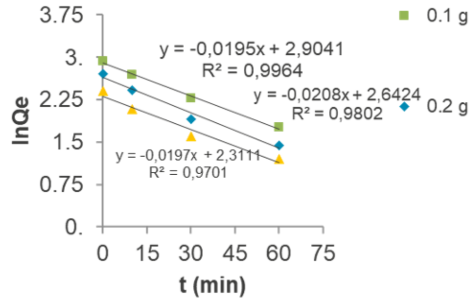
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

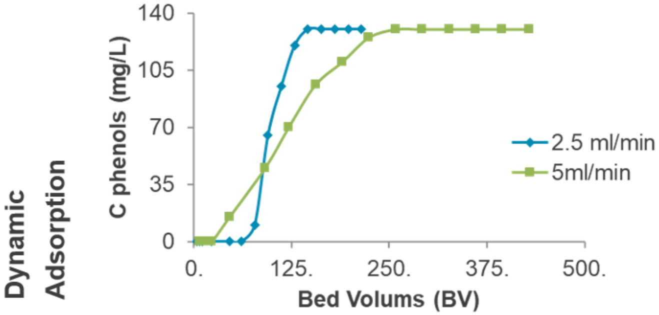
CS6: Results of the laboratory experiments

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





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

24

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

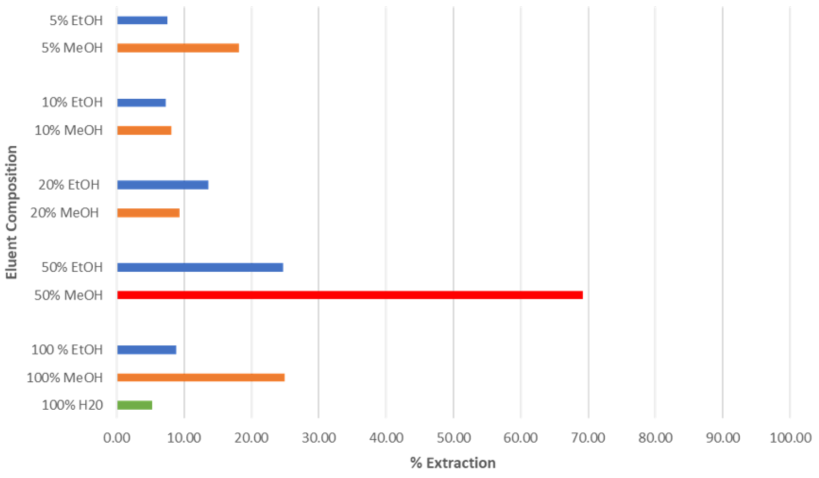
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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



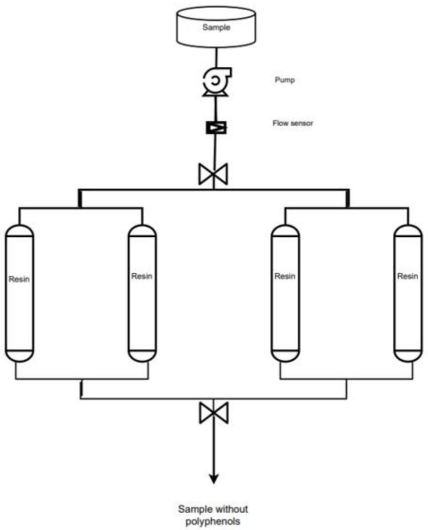
25

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

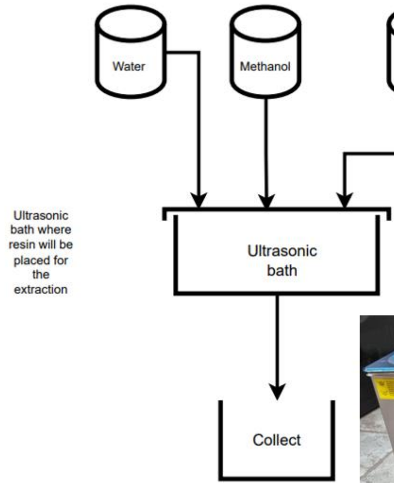
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Design and construct the pilot system

Adsorption Unit



Extraction unit



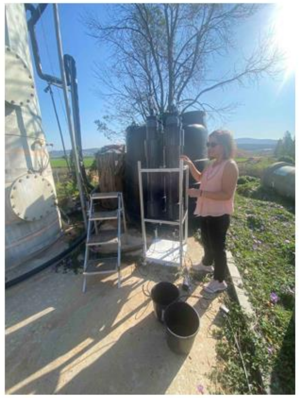
26

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

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

Installation of GtG Polyphenol Extraction Unit

- Installation of the polyphenol adsorption unit at Karmiel wastewater treatment plant
- Integration with the polyphenol adsorption unit with the high-rate anaerobic reactor
- The unit has been operating since December 2022



27

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

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

Polyphenol Extraction Testing

Adsorption steps:

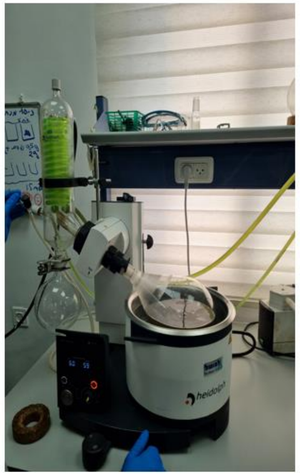
- Wastewater from olive oil mills is passed through the resin- packed bed
- Polyphenols are selectively adsorbed on the resin
- The resins are removed and transferred to the lab for testing

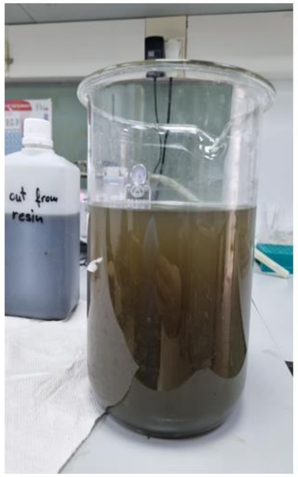
28

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

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

Polyphenol Extraction Testing





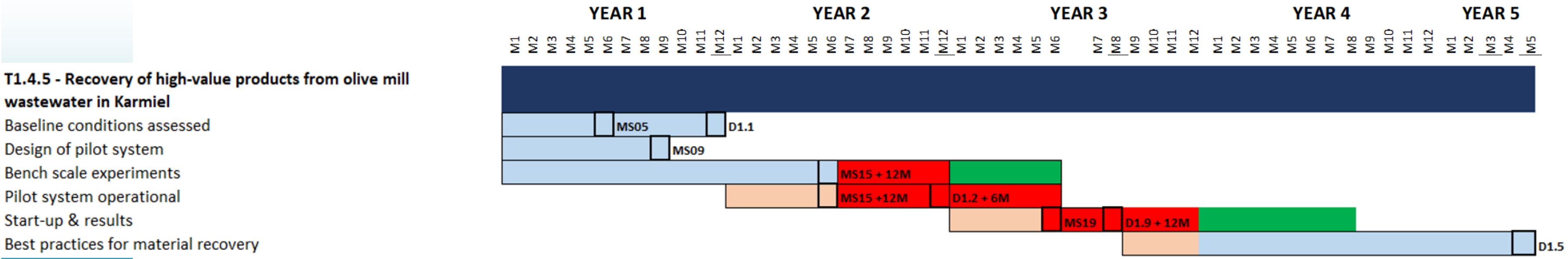
Liquid-solid extraction of polyphenols in the lab at the Galilee Society with methanol/water as the solvent

29

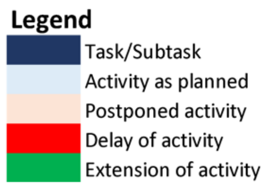
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS6: Task 1.4.5 – Timeline- Karmiel

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



→ **Pilot system start-up took place in December 2022**



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

30

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS6 Contacts

isabbah@gal-soc.org

khalid@gal-soc.org

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

2.7. CS7: Tain

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
7	1.2.6	AnMBR + RO	50%	100%	100%	Aug 22
	1.3.5	AnMBR + heat utilisation from its effluent		100%	100%	Aug 22
	1.4.6	Recovery of ammonia via stripping	>100%	100%	100%	Sep 22

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: Tain

Lead partner: Cranfield University

Other partner:

Aquabio

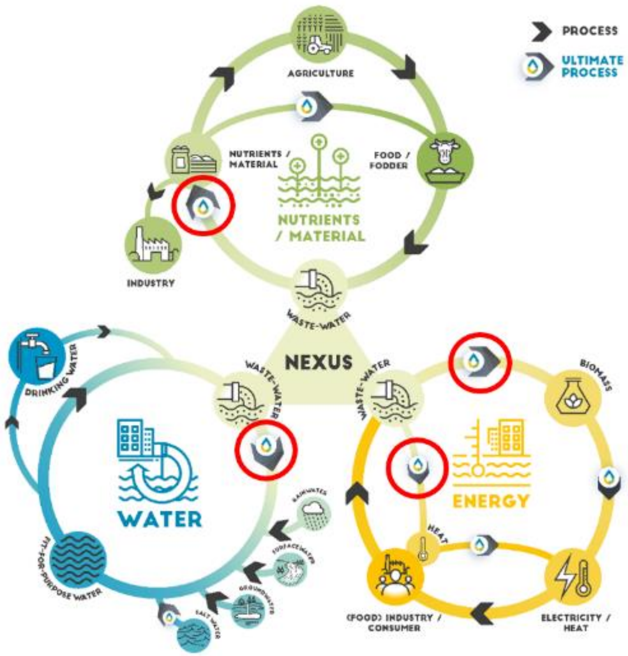
With support of:

The GLENMORANGIE COMPANY

Alpheus
part of the Anglian Water Group

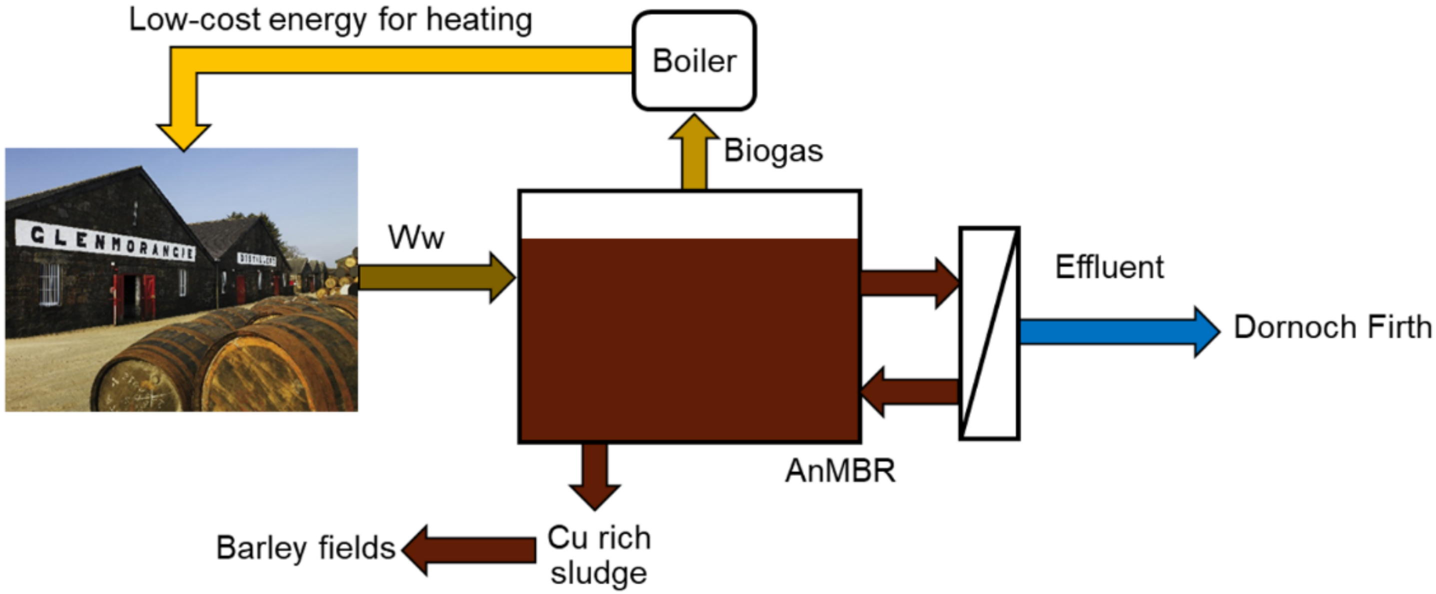
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

2



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

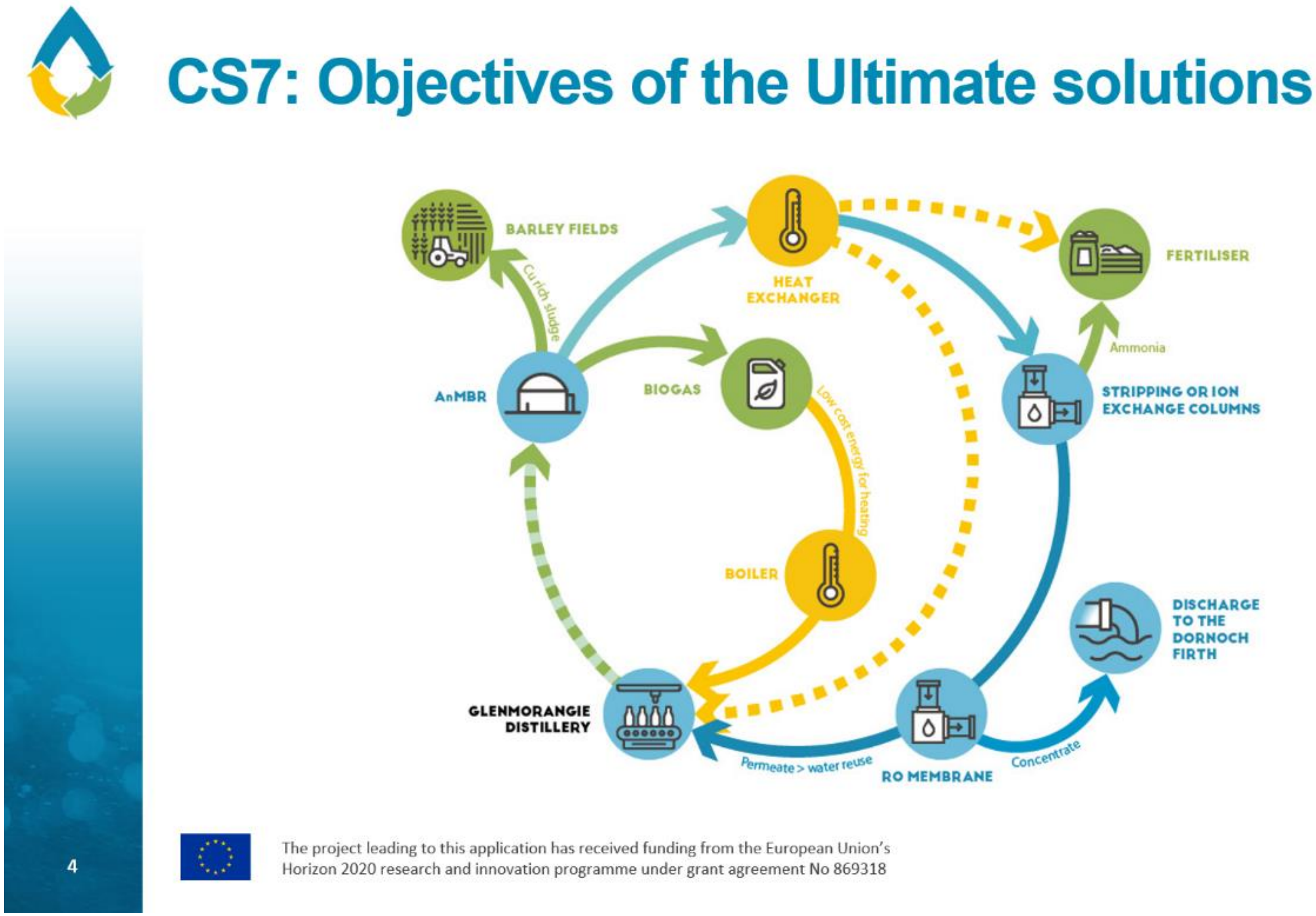
CS7: Situation before Ultimate



3

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

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

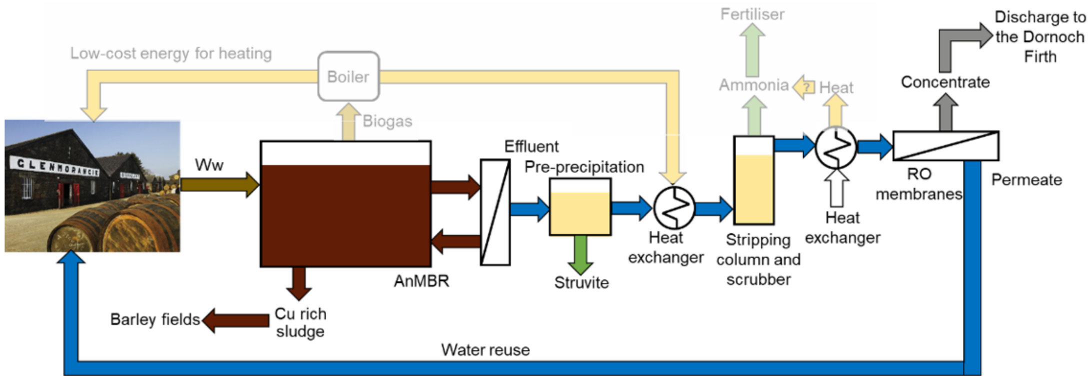


The project leading to this application has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement No 869318

CS7: 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:

- System operational and initial trials conducted

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

CS7: Results of the laboratory experiments

Subtask: 1.2.6 RO treatment of distillery wastewater after AnMBR for internal water reuse

Lab-scale trials were carried out to evaluate the impact of the reverse osmosis membranes position in the treatment train. Experiments with the different waters (anaerobically treated = raw, after precipitation and after stripping) were performed in a Sterlitech HP4750 lab-scale dead-end filtration cell using Trisep X201 RO flat sheet membranes to achieve 50% permeate recovery.

Anaerobic MBR effluent

Parameter	Value
pH	7.2 ± 0.3
Electrical Conductivity	6.0 ± 0.5 mS/cm
COD (Chemical Oxygen Demand)	554 ± 195 mg/L
TN (Total nitrogen)	804.7 ± 130.0 mg/L
TAN (Total ammoniacal nitrogen)	800.8 ± 96.0 mg/L
Phosphate	209.2 ± 24.1 mg/L

Reverse osmosis permeate

	Raw AnMBR Effluent	Raw AnMBR Effluent at pH 6.5	Precipitated AnMBR Effluent at pH 6.5	Stripped AnMBR Effluent at pH 6.5	Precipitated & Stripped AnMBR Effluent at pH 6.5
pH	8.6 ± 0.1	8.5 ± 0.3	7.6 ± 0.1	8.1 ± 0.1	8.1 ± 0.1
EC (µS/cm)	654 ± 7.8	524 ± 68.6	535 ± 16.3	1001 ± 200.1	926 ± 133.2
COD (mg/L)	<25	<25	<25	<25	<25
TN (mg/L)	111.0 ± 13.4	65.0 ± 8.7	70.0 ± 60.8	7.7 ± 0.0	6.9 ± 0.6
TAN (mg/L)	108.7 ± 15.4	53.6 ± 7.8	65.0 ± 1.2	2.5 ± 0.4	4.8 ± 0.4
Phosphate (mg/L)	4.8 ± 1.6	2.9 ± 1.0	0.7 ± 0.4	7.8 ± 2.7	0.4 ± 0.1

Reverse osmosis concentrate

	Raw AnMBR Effluent	Raw AnMBR Effluent at pH 6.5	Precipitated AnMBR Effluent at pH 6.5	Stripped AnMBR Effluent at pH 6.5	Precipitated Stripped AnMBR Effluent at pH 6.5
COD (mg/L)	984 ± 36	1065 ± 178	1174 ± 9	1389 ± 127	1178 ± 59
TAN (mg/L)	1379.1 ± 30.7	1468.0 ± 80.6	1273.3 ± 64.0	12.8 ± 1.1	46.0 ± 0.7
Phosphate (mg/L)	326 ± 0.0	346.7 ± 8.1	25.3 ± 2.3	414.0 ± 11.0	23.6 ± 1.4

The RO permeate obtained from the water pre-treated through precipitation and stripping delivers the best quality for reuse. However, the RO concentrate obtained directly from the treatment of the anaerobic MBR effluent provides a more concentrated source of nutrients in a smaller volume which would make the nutrients recovery step more sustainable.

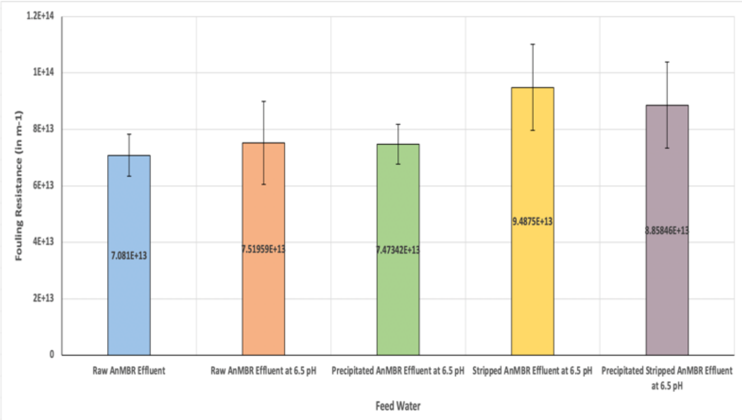
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

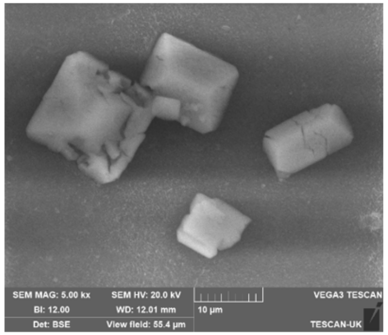
CS7: Results of the laboratory experiments

Subtask: **1.2.6 RO treatment of distillery wastewater after AnMBR for internal water reuse**

Experimental trials on different feed waters in a Sterlitech HP4750 lab-scale dead-end filtration cell using Trisep X201 RO flat sheet membranes to achieve 50% permeate recovery.



Interestingly, the fouling resistance in the RO membranes was found to be slightly higher with the water which went through stripping first due to the increase in salts after pH adjustment.
However, due to the nature of the water, the effluent from the anaerobic MBR (labelled raw here) produced a more complex fouling with struvite crystals identified on the surface of the membrane.



Overall, pH adjustment (increase for the precipitation and stripping steps and decrease for the RO filtration) significantly increases the salt concentration in the water.
The sequence of the technologies in the treatment train can be adpated but it will lead to trade-offs between membrane fouling, resource recovery potential and quality of water for reuse.

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

7

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: Pictures and initial results of the technology

Subtask: 1.2.6 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. The system is fitted with TriSep 1812 X20 membrane elements. Trials were so far conducted in batch to evaluate the operability of the unit to meet a water recovery of 50%.

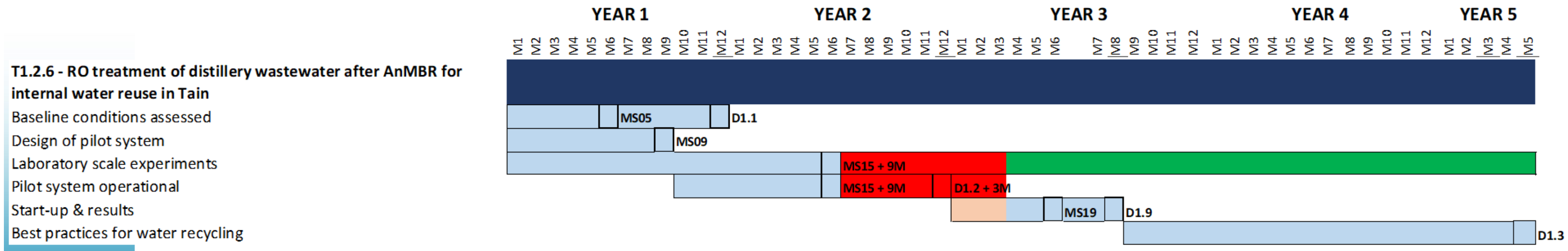
8

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

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

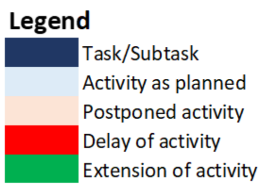
CS7: Task 1.2.6 - Timeline

Subtask: 1.2.6 RO treatment of distillery wastewater after AnMBR for internal water reuse



→ **Pilot scale experiments started in August 2022 (M27)**

→ **Additional lab scale experiments will continue to be carried out in parallel to the operation of the pilot unit to help further support the evaluation**



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

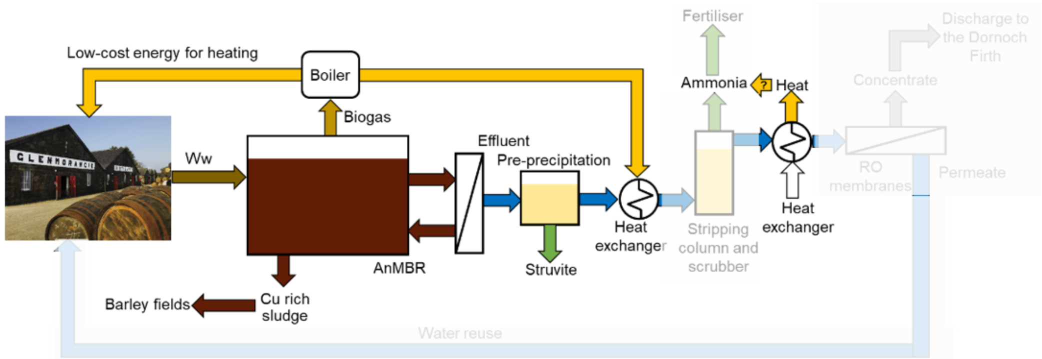
9

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: 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 from the AnMBR effluent utilized in subsequent treatment steps



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:
- System operational and initial trials conducted

10

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

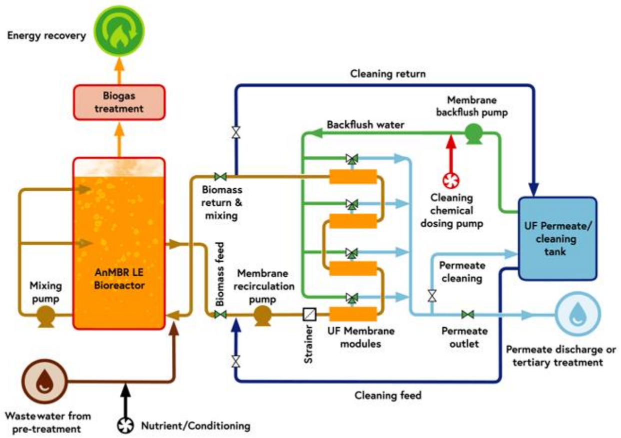
CS7: First results of the new technologies

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

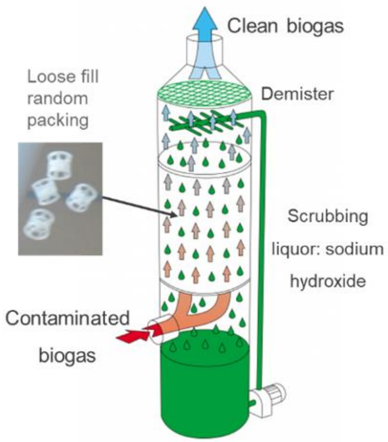
The biogas produced in the AnMBR first goes through a scrubber for H_2S removal and is then converted to steam in a boiler.

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 (Nm³/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 (°C)	188
Working pressure	8 barg

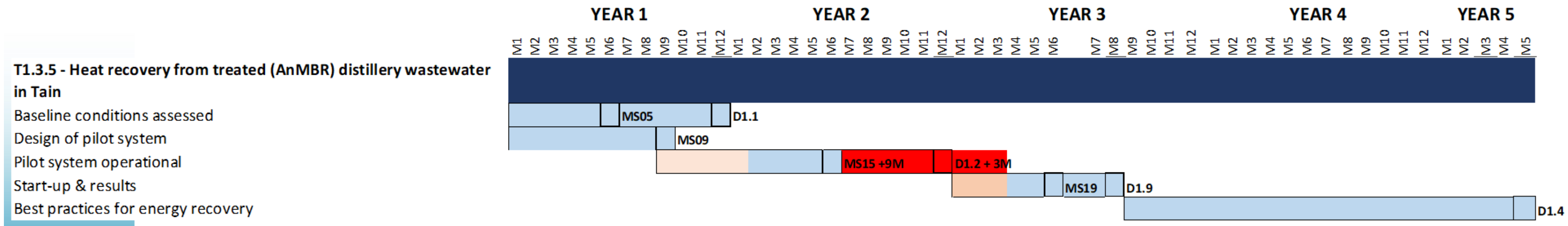
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

11

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: Task 1.3.5 - Timeline

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



→ Residual heat utilisation trials were started in August 2022 (M27) to evaluate the impact of temperature in the reverse osmosis membrane and further trials will be carried out in the nutrients recovery steps.

→ Monitoring of the biogas and steam productions from the full scale AnMBR continues

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

12

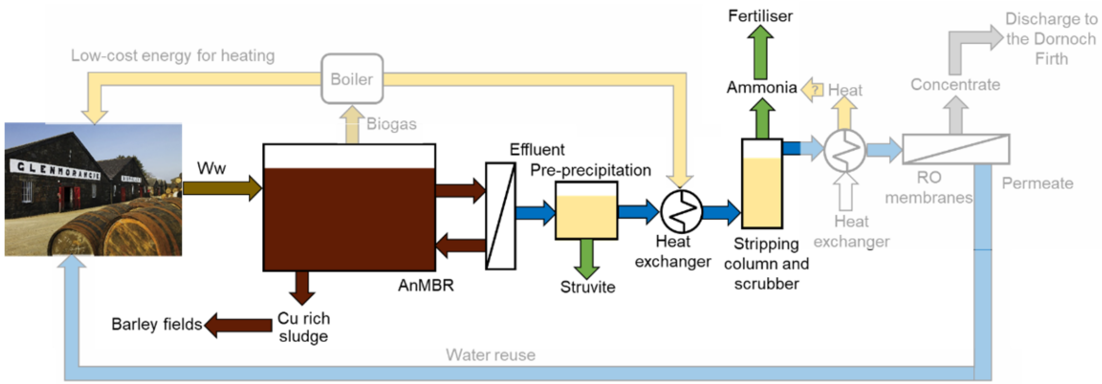
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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: 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

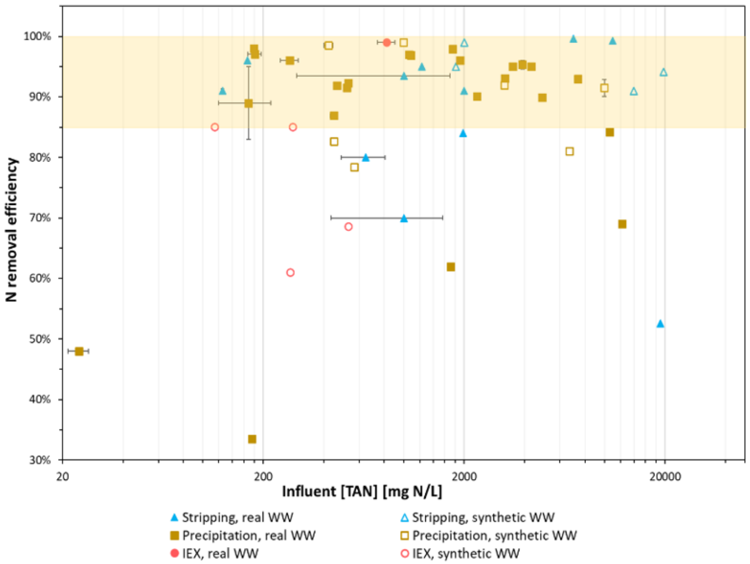
Status/progress:
- System operational and initial trials conducted

13

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 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.

14

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

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: Pictures of the struvite precipitator and ammonia stripping unit

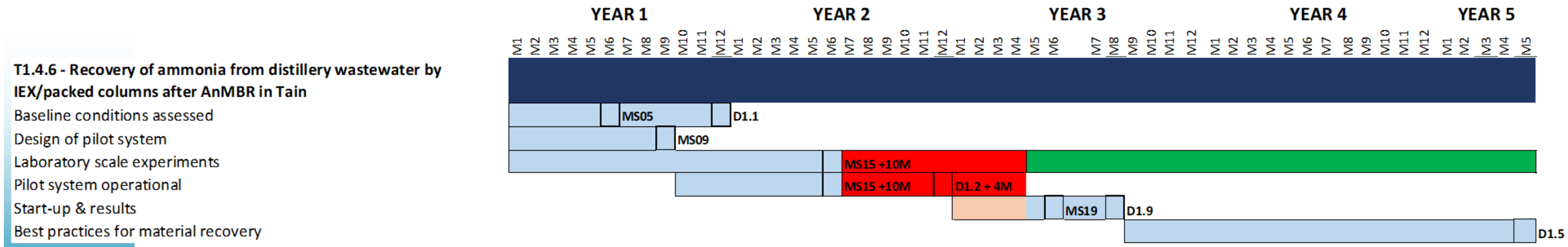
Subtask: **1.4.6 Recovery of ammonia from distillery wastewater after AnMBR**

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

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: Task 1.4.6 - Timeline

Subtask: **1.4.6 Recovery of ammonia from distillery wastewater after AnMBR**



→ **Nutrients recovery systems were commissioned in September 2022 (M28).**

→ **The pilot and lab scale experiments will continue in parallel until the end of the project**

Legend

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

16

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

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

CS7 Contacts

m.pidou@cranfield.ac.uk

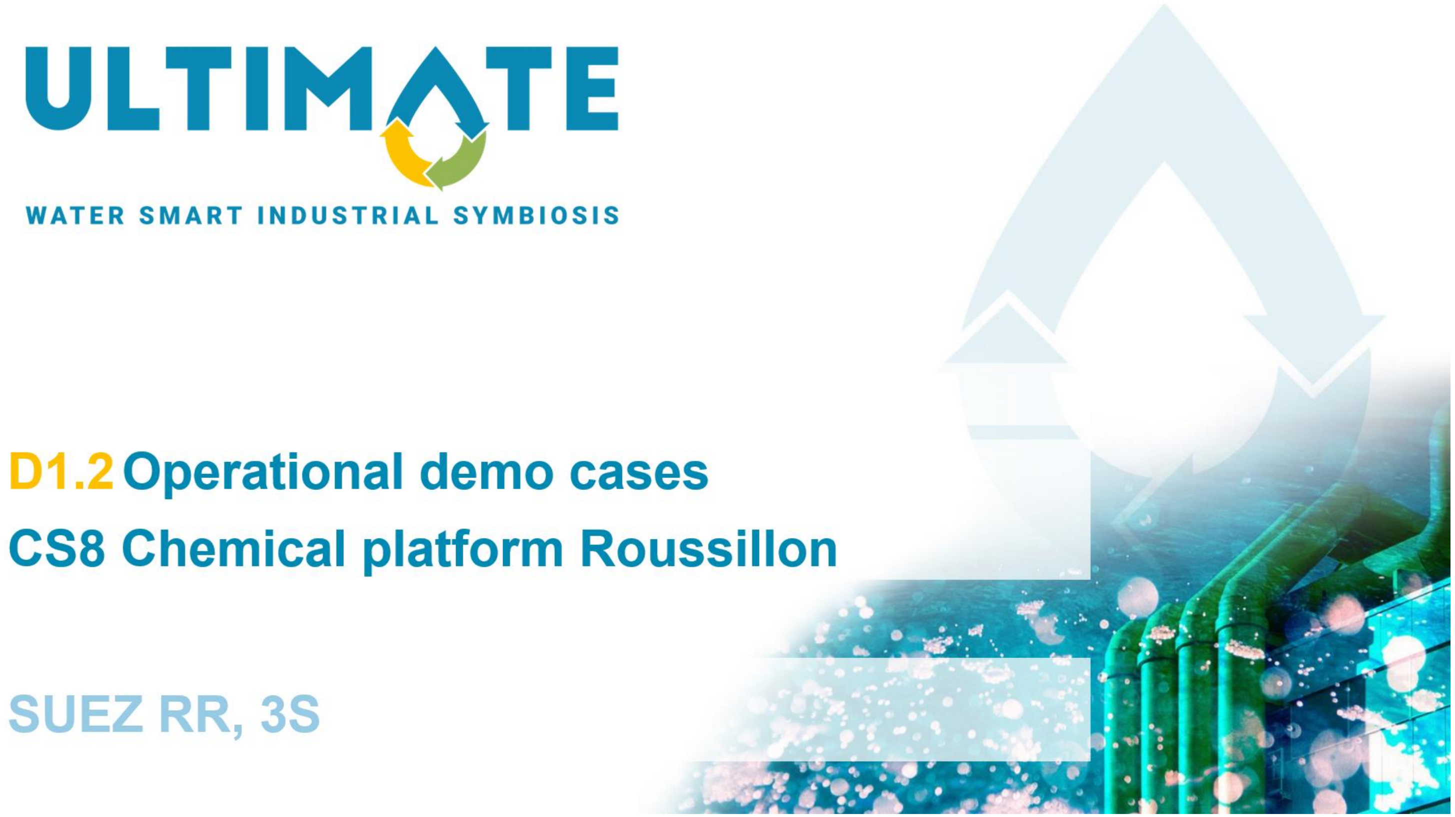
M.M.Gritti@cranfield.ac.uk

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

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			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
8	1.3.6	Feasibility study: heat recovery	No pilot plant --> excluded from D1.2			
	1.4.7	Laboratory pilot: sulphur recovery	90%	100%	100%	Oct. 22
		Industrial pilot: sulphur recovery		35%	0%	Aug 23
		Feasibility study: metal recovery	No pilot plant --> excluded from D1.2			



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

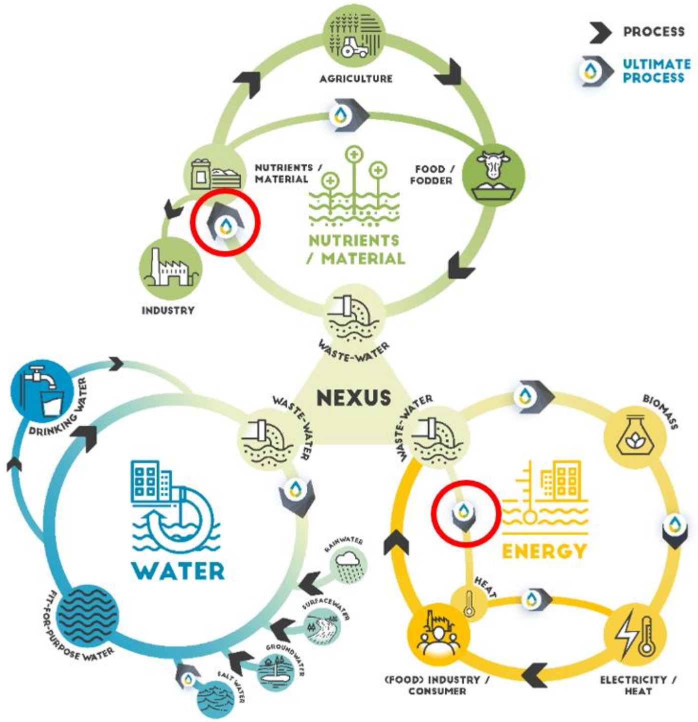
CS8: Chemical platform of Roussillon

Lead partner:

SUEZ RR IWS Chemicals

Other partner:

SUEZ Smart Solutions

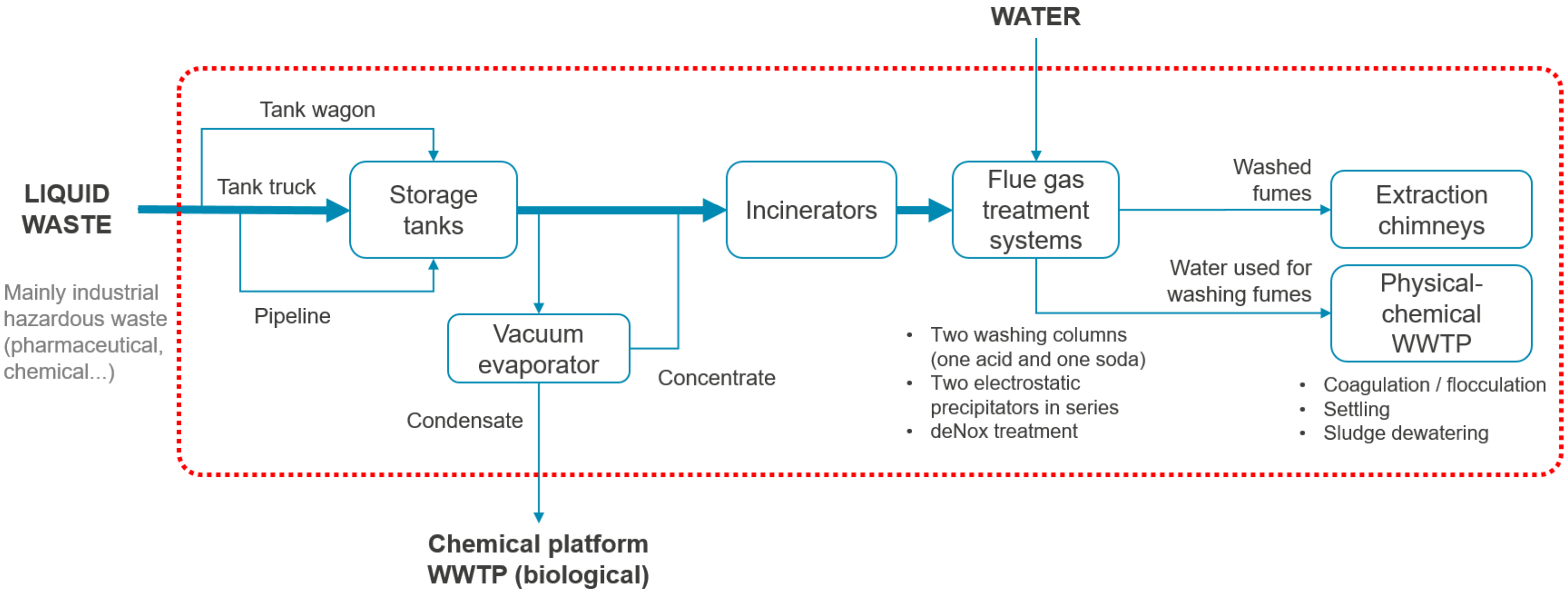


2

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

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

CS8: Situation before Ultimate

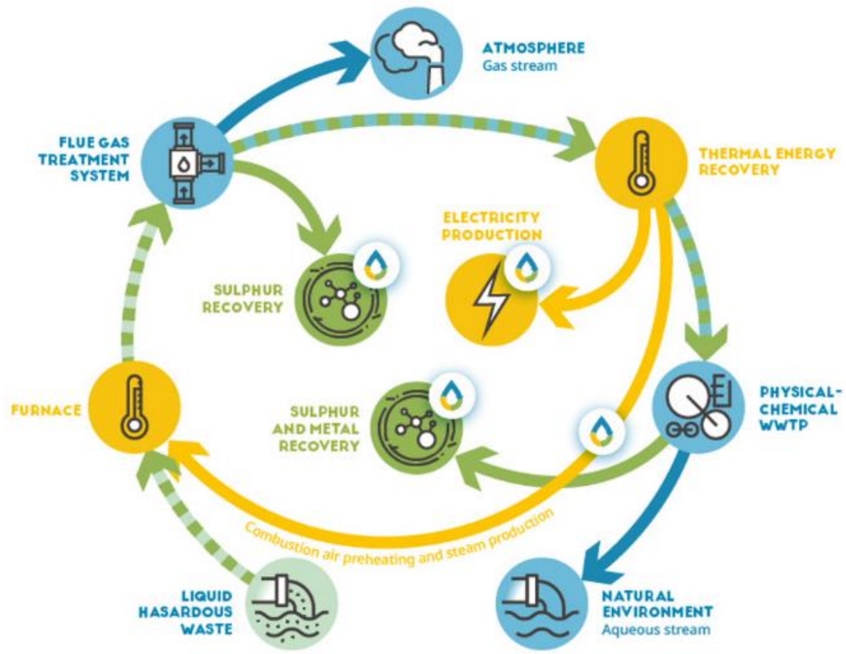


3

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

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

CS8: Objectives of the Ultimate solutions

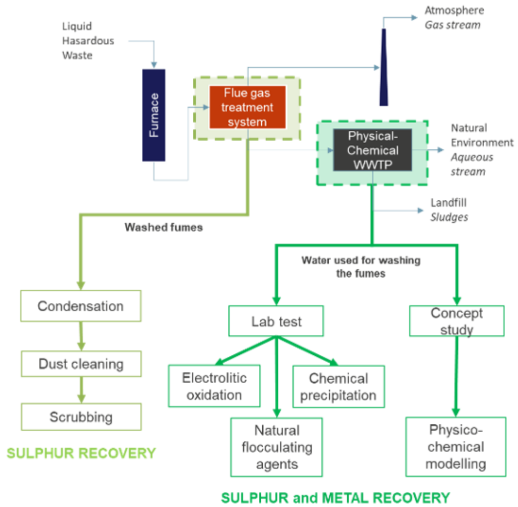


4

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

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

CS8: Status/progress



Subtask: 1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon

Baseline technology: no Sulphur nor metals 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
- **Metals recovery**: concept study and physical-chemical modelling (calculation of metal speciation, solubility equilibria, complexation reactions).

TRL: 4 → 6 (Sulphur recovery); **2 → 4** (metals recovery)

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

Quantifiable target: Sulphur from flue gas: 80% Sulphur recovery; **Sulphur from effluent WWTP**: 80% Sulphur recovery

Status/progress:

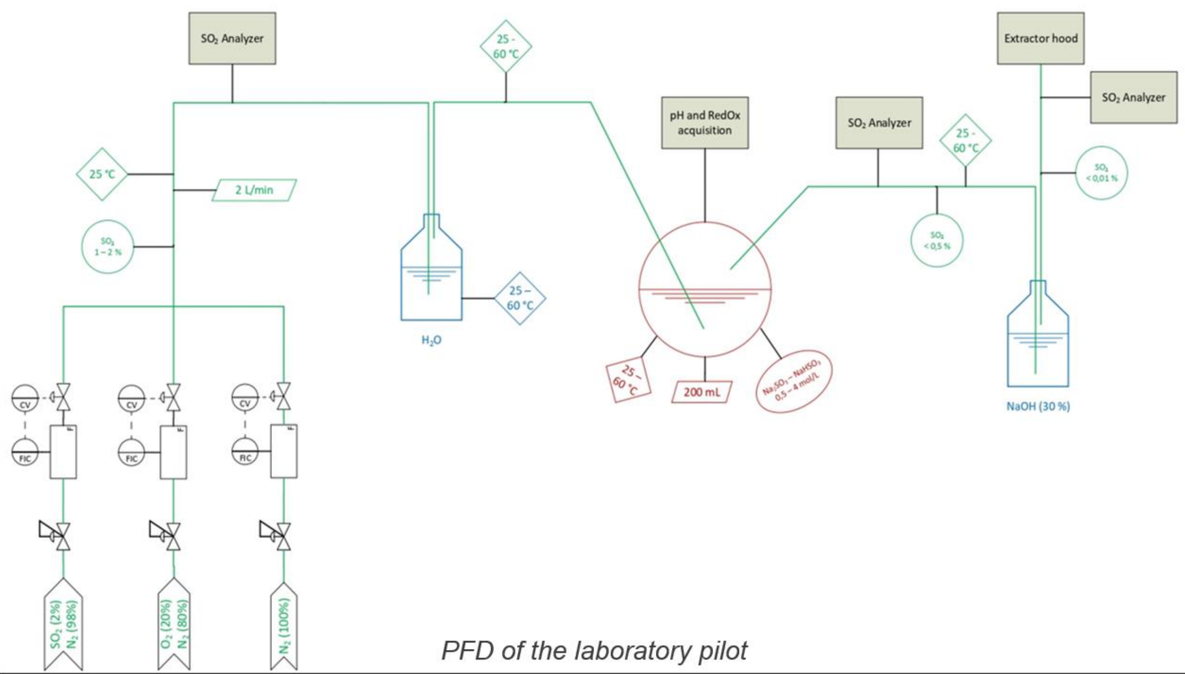
- **Sulphur from flue gas:** Laboratory pilot plant is operational & industrial pilot is under construction
- **Sulphur from effluent WWTP:** The lab tests will start in M37
- **Metals:** this task will be conducted on another plant of IWS Chemicals (Le Pont-de-Claix) and started in M34

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

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

CS8: The laboratory pilot

Subtask: 1.4.7 Recovery of Sulphur and metals 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.

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

6

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

CS8: The laboratory pilot

Subtask: 1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon

Gas mixture :

Allows to study :

→ The SO_2 level (0,1 to 1 %) ;

→ The O_2/SO_2 ratio (5 to 20).

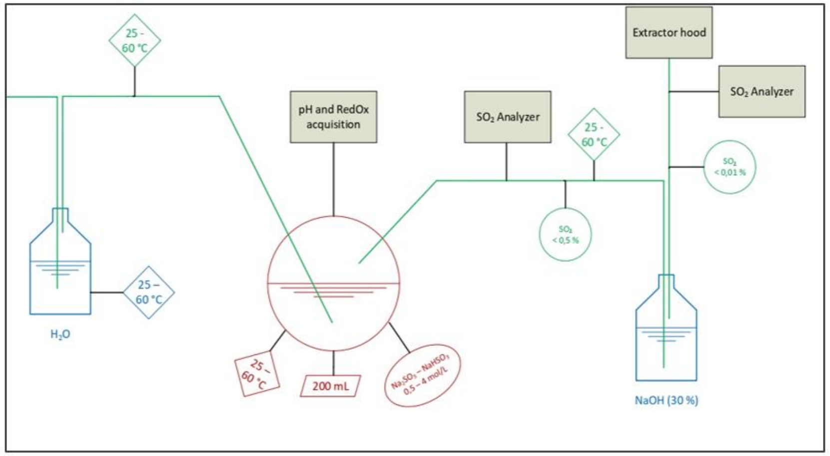
Analysis :

→ SO_2 analyzer ;

→ Test kits (liquid phase characterization) ;

→ pH sensor ;

→ RedOx potential sensor.

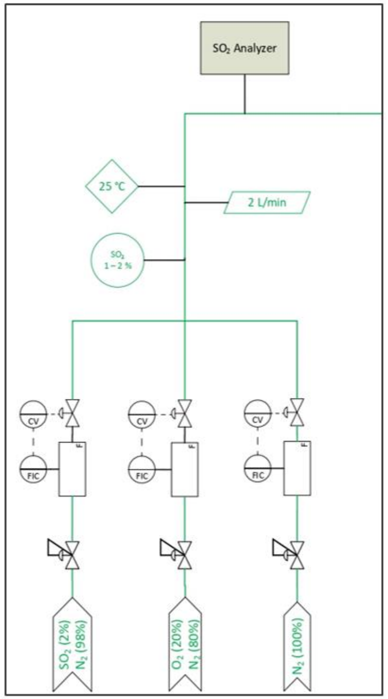


PFD of the laboratory pilot : Focus on the reactor

Other parameters :

→ Temperature (40 to 60 °C) ;

→ Initial composition of the liquid phase (0,1 to 1,5 mol/L Na_2SO_3).



PFD of the laboratory pilot : Focus on the gas mixture

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

7

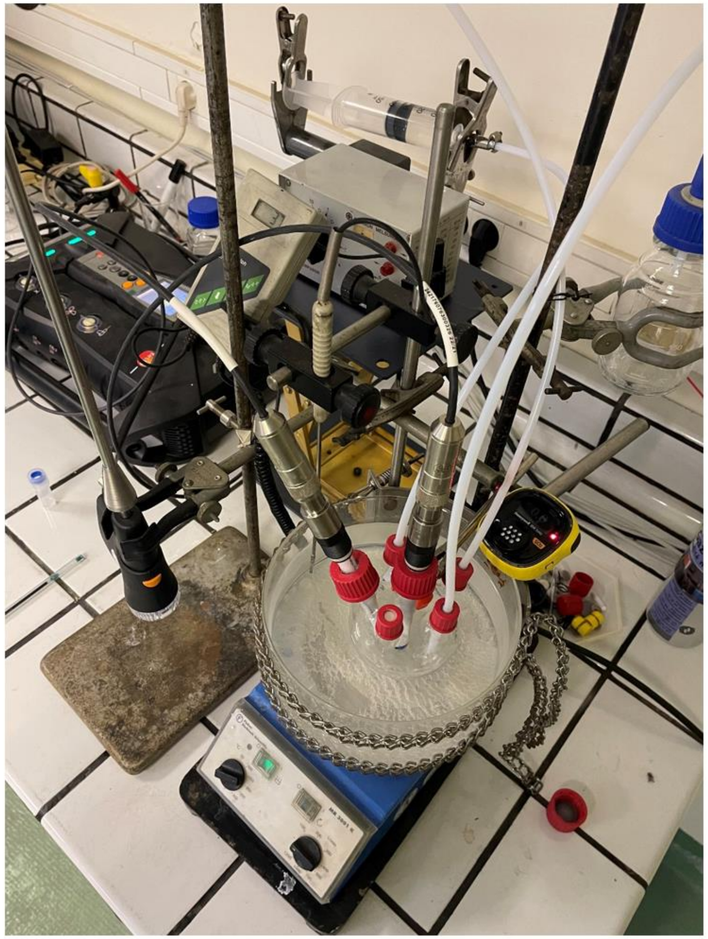
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS8:

picture of laboratory pilot to recover sulphur from flue gas

8

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

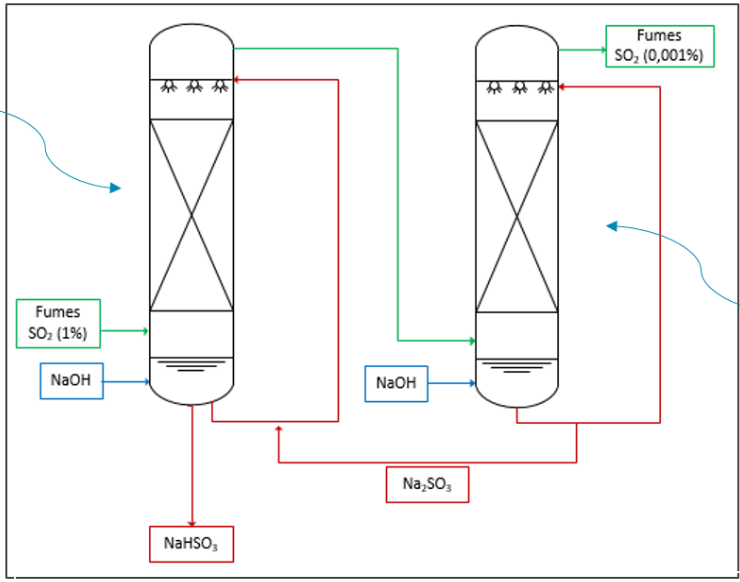


The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

CS8: The industrial pilot

Subtask: **1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon**

Concentrate the solution



Absorb the remaining SO_2

Principle of the industrial pilot

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

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

CS8: The industrial pilot

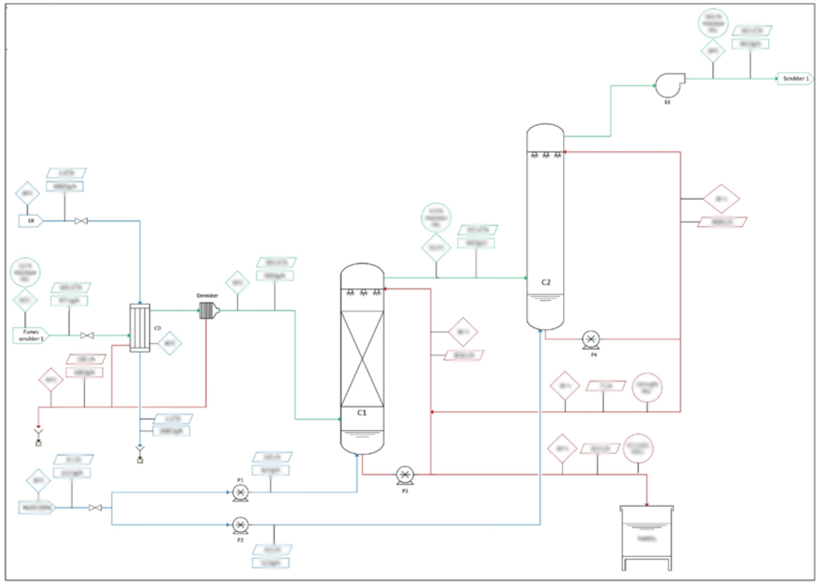
Subtask: **1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon**

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

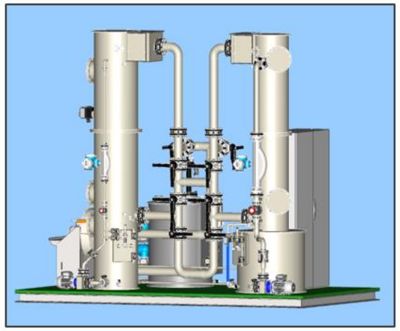
10

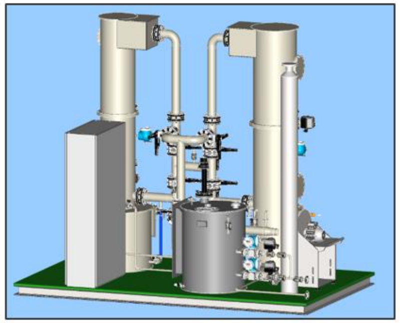
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

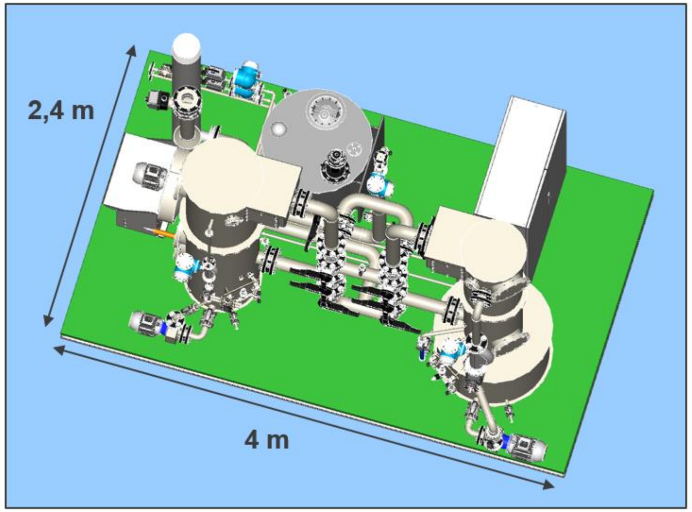
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

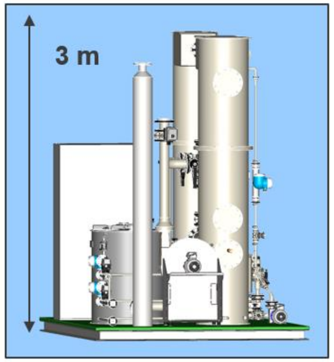
The industrial pilot – 3D model

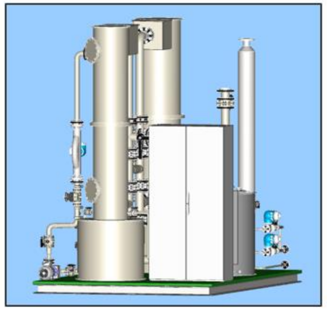
Subtask: **1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon**











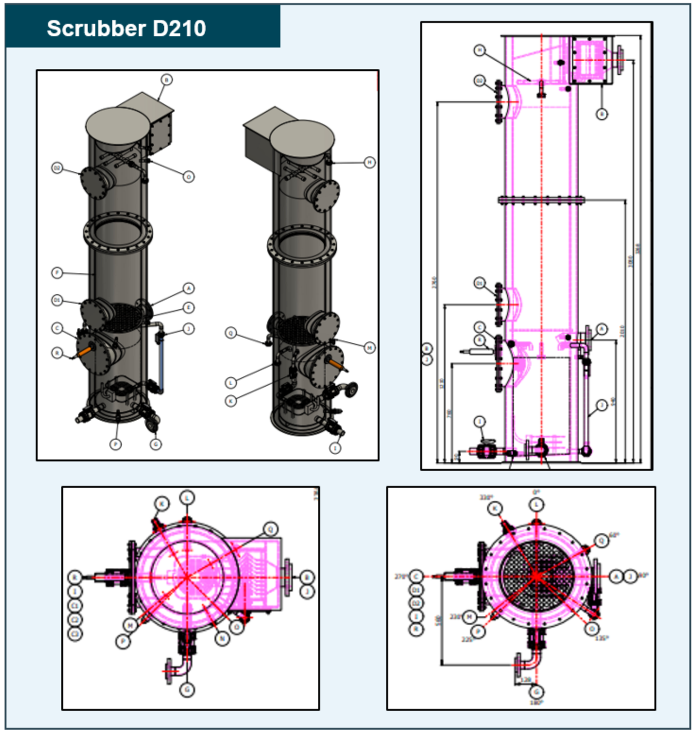
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

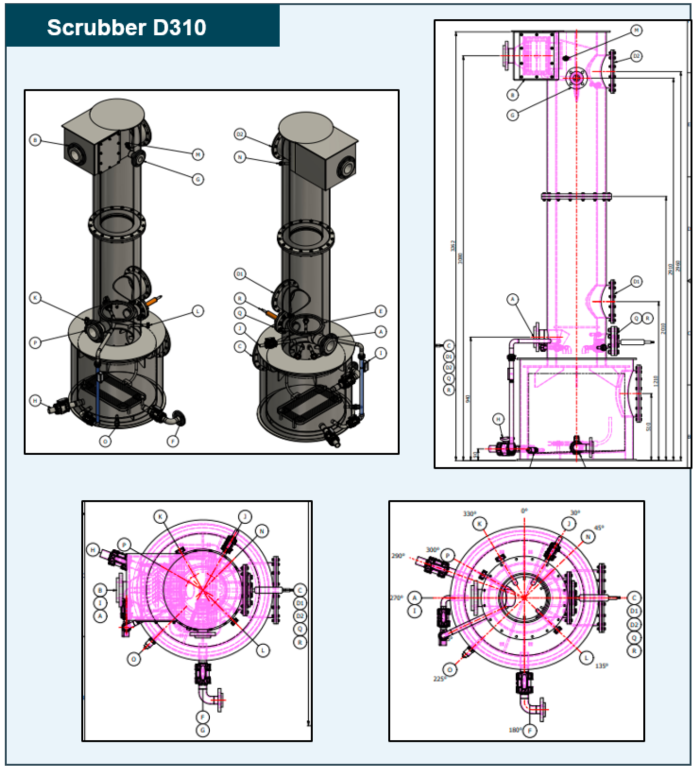
11

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

The industrial pilot – Scrubbers

Subtask: 1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon





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

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

The industrial pilot – Manufacture

Subtask: 1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon

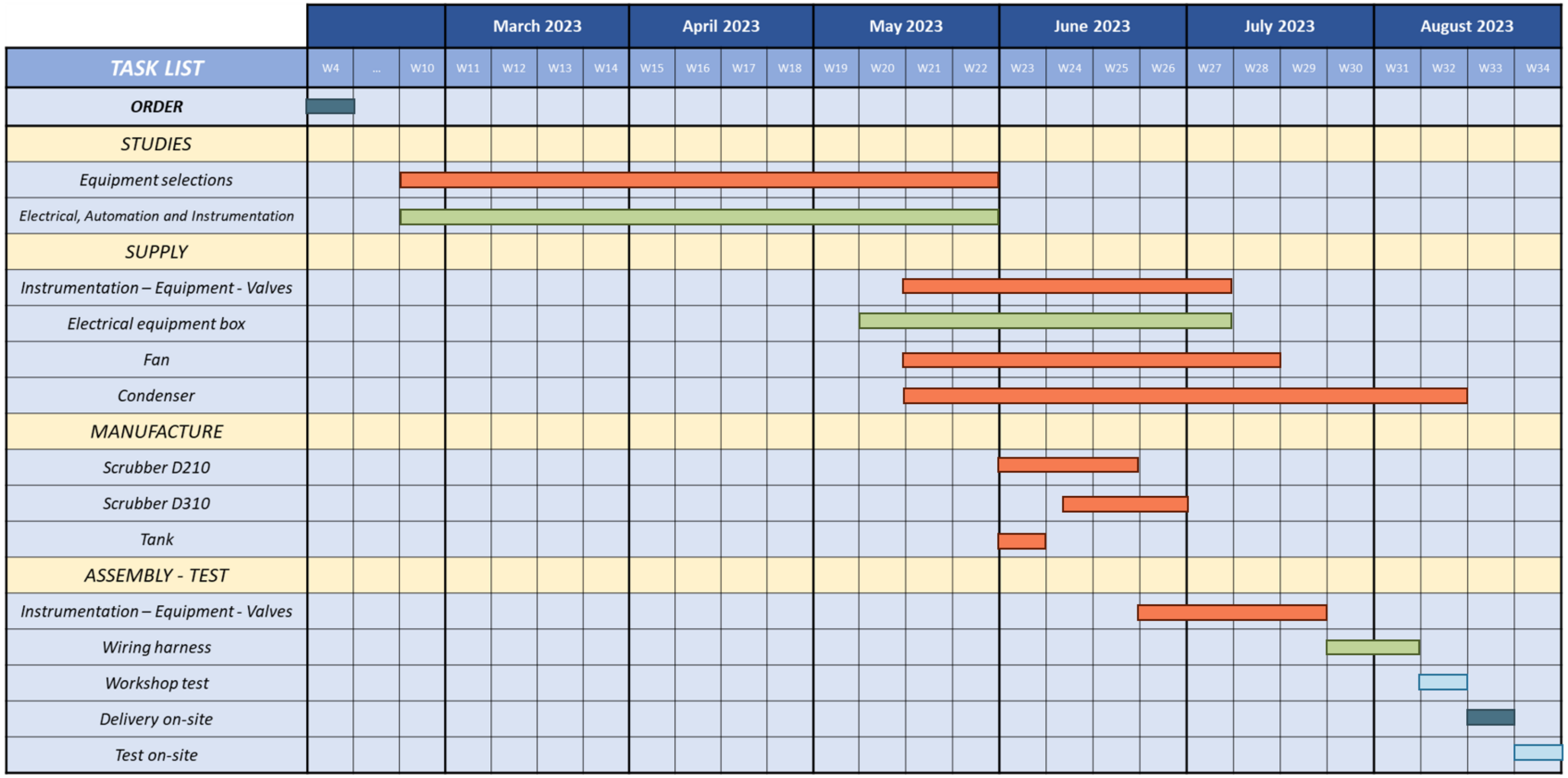
Scrubber D210
(Lower part)

Scrubber D310
(Lower part)

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

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

The industrial pilot – Schedule



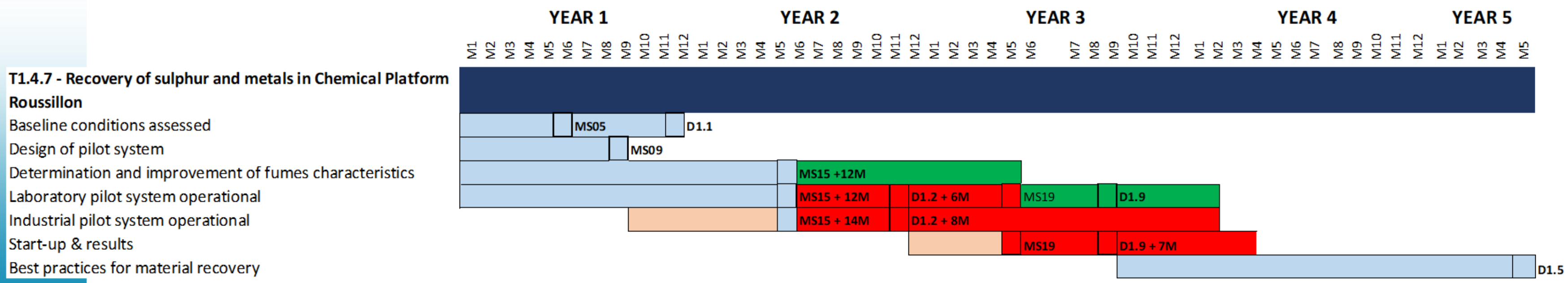
14

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

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

CS8 Timeline

Subtask: **1.4.7 Recovery of Sulphur and metals at the chemical platform of Roussillon**



→ **Laboratory pilot system is operational since Oct. 2022**

→ **Industrial pilot plant is expected to be operational : August 2023 (M39)**

→ **Still enough time to conduct the planned investigations in the industrial pilot**

15

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

ULTIMATE
WATER SMART INDUSTRIAL SYMBIOSIS

CS8 Contacts

anne.reguer@suez.com
stephane.deveughele@suez.com

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

2.9. CS9: Kalundborg

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
9	1.2.7	Novel UF membrane		100%	100%	Jun 21
	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			

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

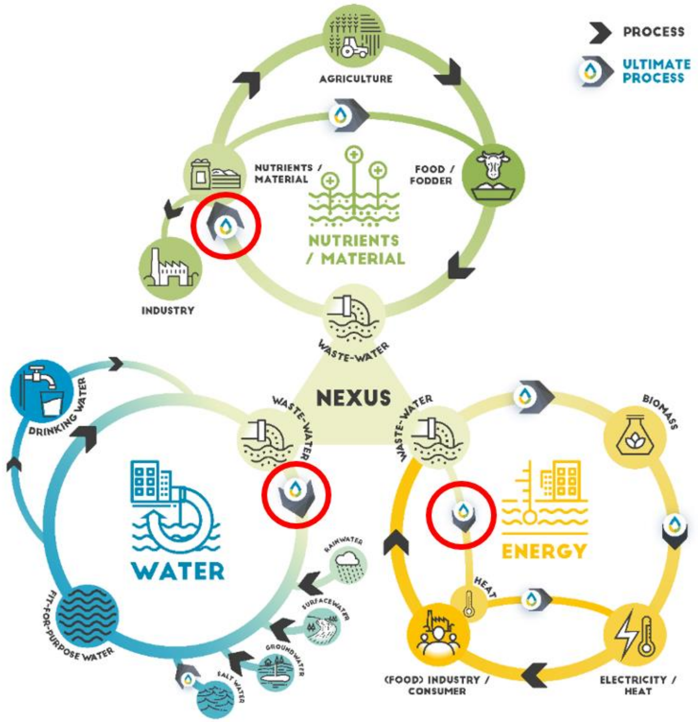
CS9: Kalundborg

Lead partner: KALUNDBORG FORSYNING

Other partners: PENTAIR X-FLOW

KWB

novozymes Rethink Tomorrow



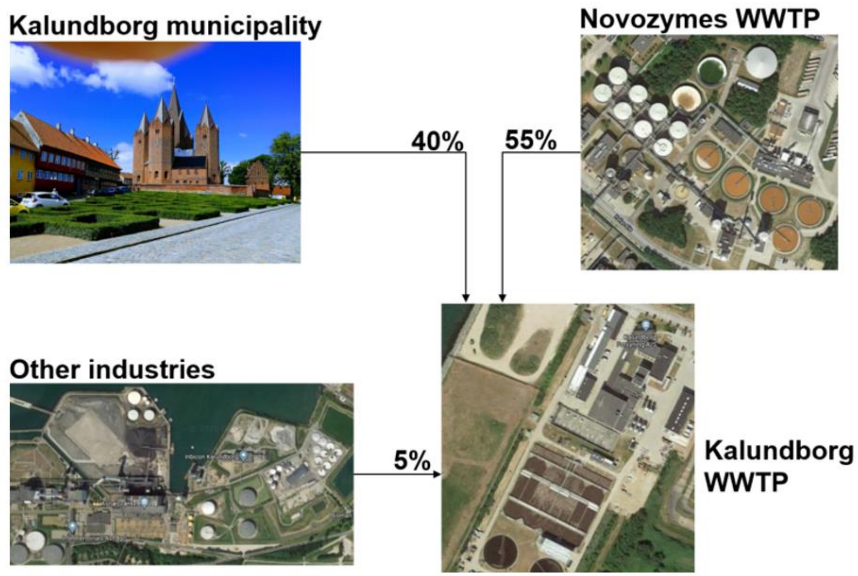
2

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

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

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



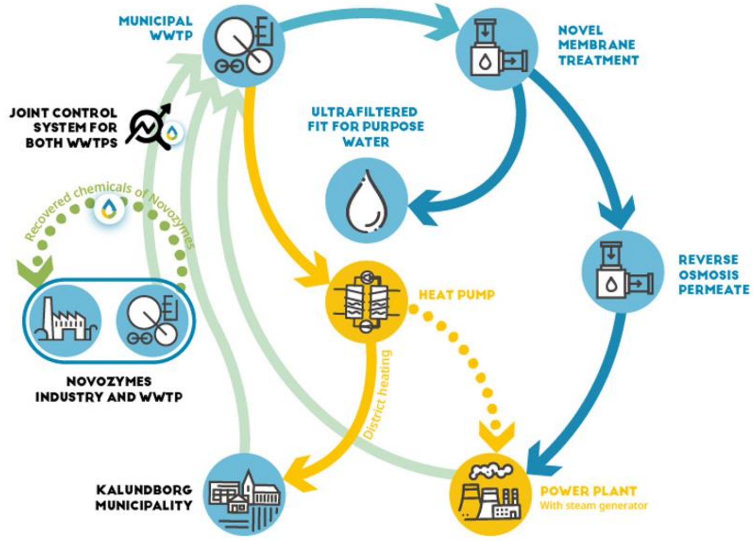
3

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

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

CS9: Project objectives in Kalundborg:

- **Production of fit-for-purpose water** using a novel membrane pre-treatment for wastewater with high a fraction of 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**



4

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

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

CS9: Pilot plant: fit-for-purpose water production

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

- nanofiltration (NF) or novel ultra-tight ultrafiltration (UF) as pre-treatment for reverse osmosis (RO)

TRL 5 → 7

Capacity 2 m³/h

Ambition beyond the project

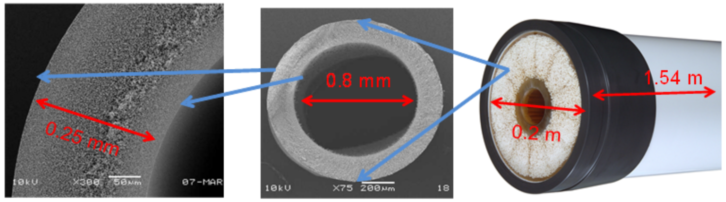
- > 70,000 m³/a fit-for-purpose water production
- > 40% reduction of surface water through reuse of treated water

Status/progress

- Pilot plants in operation since June 2021

Novel ultra-tight ultrafiltration membrane

- Molecular weight cut off: 4 kDa
- Filtration: inside out



Fibre wall Fibre Module head

- Material: (modified) polyethersulphone with LbL

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

5

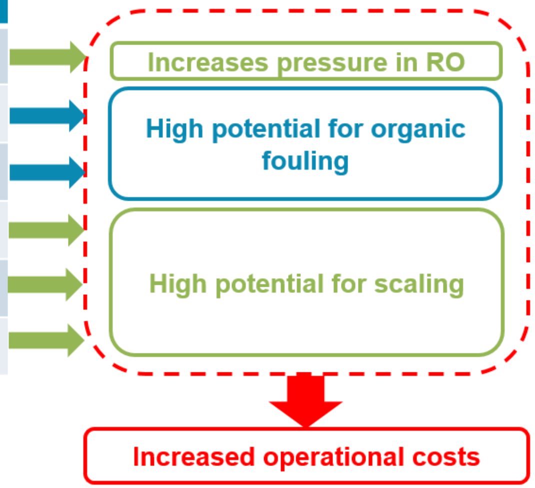
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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
Sulfate	mg/L	440-510

* before ozonation for COD removal



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

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

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 or nanofiltration membrane prevent better the RO from fouling than a conventional UF?

➢ Conventional UF membrane, novel UF membrane and nanofiltration 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

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

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

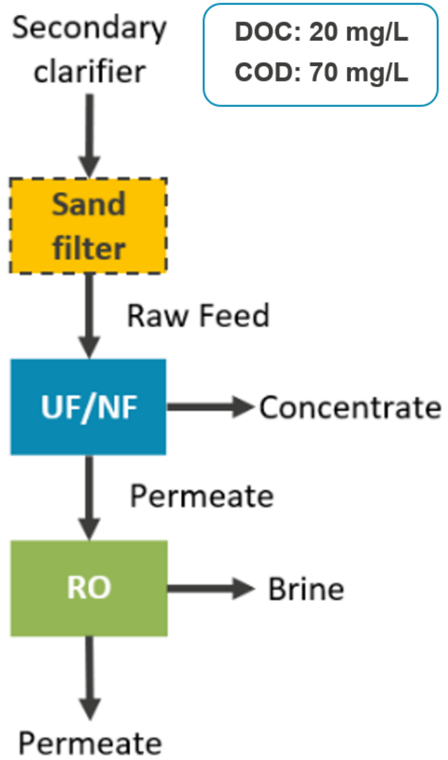
CS9: Treatment trains for water recovery

COD	Chemical oxygen demand
DOC	Dissolved organic carbon
NF	Nanofiltration
RO	Reverse Osmosis
UF	Ultrafiltration
WWTP	Wastewater treatment plant

8

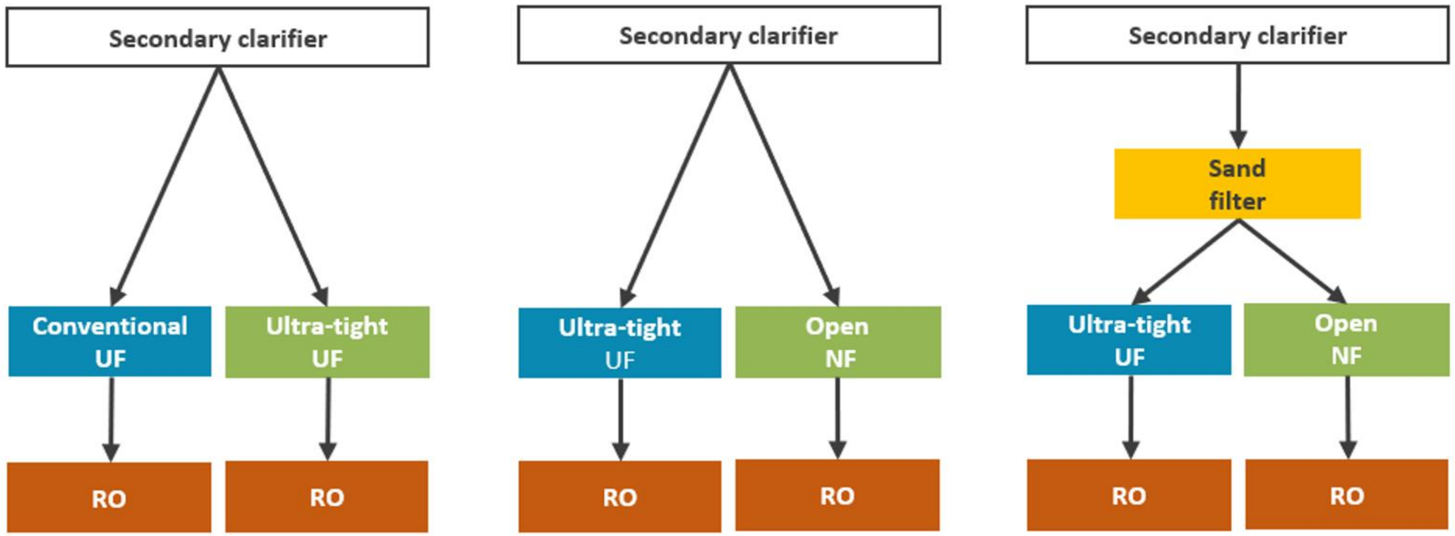
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Effluent from municipal WWTP:



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

CS9: Different variants of tested treatment trains



9

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

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

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

10

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

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

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)

11

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

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)

These videos are accessible via the indicated links below this presentation on the ULTIMATE webpage.

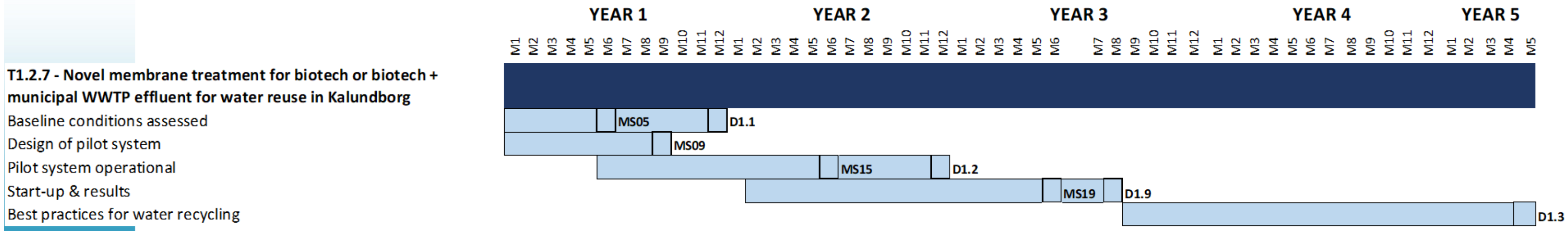
12

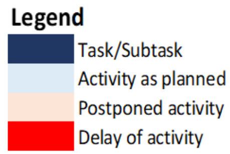
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

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

CS9: Task 1.2.7 is in time

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





- **Pilot is operational & results obtained: task is in time**

➢ Due to the energy crises, the ozonation facility at the municipal WWTP was shut down. Hence, ozonation as a pre-treatment option for the water recovery treatment train cannot be investigated.

➢ In addition to the foreseen Dynasand filter, a dual media filter was installed alternatively and is being investigated as pre-treatment option.

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

13

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

ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

Contacts

anne.kleyboecker@kompetenz-wasser.de
jeannette.jaehrig@kompetenz-wasser.de
leo.vredenbregt@pentair.com
lirm@kalfor.dk
prth@kalfor.dk

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

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

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, 17 laboratory and preparatory experiments and investigations of existing systems are conducted to test the ULTIMATE approaches and based on them, 24 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 M37.

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 to material recovery in Lleida (CS5) and another one to energy recovery in Karmiel (CS6).

Until M27, five additional plants were operational. Two of them refer to water recovery in Lleida (CS5) and Tain (CS7), one to material reuse in Rosignano (CS3) and two to energy recovery and reuse in Shafdan (CS6) and Tain (CS7).

Until M30, six additional pilots were put into operation. Two relate to water recovery and are located in Tarragona (CS1). One was implemented in Nieuw Prinsenland (CS2) and focuses on both water recovery and material recovery. The other three pilots refer to material recovery and were put into operation in Napflio (CS4), Tain (CS7) and at the Chemical Platform of Roussillon (CS8).

Since M33, four additional pilots are operational in Lleida (CS5) and in Karmiel (CS6) referring to energy recovery and material recovery, respectively.

In the course of the project, three pilots had been included in the description of work in addition. Due to their later inclusion, they have a different time planning and hence, two of them are not operational yet. They will be located in Rosignano (CS3) and are expected to be operational in September 2023 and in January 2024. Furthermore, the full-scale electrostimulated anaerobic reactor (ELSAR, CS5) has also another time planning and is expected be operational in September 2023 as the industrial pilot plant of CS8 is at the Chemical Platform of Roussillon.

Table 3 provides an overview about the progress of the pilot systems and of the laboratory experiments. Eight WSISs conducted laboratory experiments. In total, 17 different laboratory experiments and/or investigations of already existing facilities were and 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

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

to pilot scale. Eleven of the 17 investigations are already completed and four 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 to material recovery in Lleida (CS5) and another one to energy recovery in Karmiel (CS6).

Until M27, five additional plants were operational. Two of them refer to water recovery in Lleida (CS5) and Tain (CS7), one to material reuse in Rosignano (CS3) and two to energy recovery and reuse in Shafdan (CS6) and Tain (CS7).

Until M30, six additional pilots were put into operation. Two relate to water recovery and are located in Tarragona (CS1). One was implemented in Nieuw Prinsenland (CS2) and focuses on both water recovery and material recovery. The other three pilots refer to material recovery and were put into operation in Napflio (CS4), Tain (CS7) and at the Chemical Platform of Roussillon (CS8).

Since M33, four additional pilots are operational in Lleida (CS5) and in Karmiel (CS6) referring to energy recovery and material recovery, respectively.

In the course of the project, three pilots had been included in the description of work in addition. Due to their later inclusion, they have a different time planning and hence, two of them are not operational yet. They will be located in Rosignano (CS3) and are expected to be operational in September 2023 and in January 2024. Furthermore, the full-scale electrostimulated anaerobic reactor (ELSAR, CS5) has also another time planning and is expected be operational in September 2023 as the industrial pilot plant of CS8 is at the Chemical Platform of Roussillon.

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

Table 3 Overview about the progress regarding the construction and the operation of the pilot plants: CS3 and CS5 are constructing three pilot plants that are excluded from D1.2 due to another time planning

Overview			D1.2: Operational demo cases			
CS	Subtask	Technology or treatment train	Laboratory experiments or investigations	Pilot plant constructed	Pilot plant operational	Operational since/ to be expected
1	1.2.1	RO + MD; ammonia removal via zeolites	100%	100%	100%	Nov 22
2	1.2.2	Reclamation of water using electrodialysis	75%	100%	100%	Nov 22
2	1.3.1	Feasibility study: HT-ATES	No pilot plant --> excluded from D1.2			
2	1.4.1	Recovery of nutrients: test beddings & demo greenhouse	75%	100%	100%	Nov 22
3	1.2.3	Control system to avoid high chlorine concentrations	No pilot plant --> excluded from D1.2			
3	1.4.2	Use of byproducts: pilot scale adsorption system	100%	100%	100%	Jul 22
3	1.4.2	Use of byproducts: clari-flocculation pilot	100%	10%	0%	Jan 24
3	1.4.2	AOP pilot system	60%	100%	0%	Sep 23
4	1.2.4	Water recovery: filtration, AOP, SBP	100%	100%	100%	May 22
4	1.4.3	Recovery of antioxidants: adsorption/extraction	100%	100%	100%	Nov 22
5	1.2.5	Monitoring system for fouling in AnMBR	No pilot plant --> excluded from D1.2			
5	1.2.5	(NF + RO) + (AOP + UV)	100%	100%	100%	Jan./Jun. 22
5	1.3.2	AnMBR	100%	100%	100%	Dec. 22
5	1.3.2	Pilot ELSAR	100%	100%	100%	Dec. 22
5	1.3.2	Full-scale ELSAR		50%	0%	Sep 23
5	1.3.2	SOFC		100%	100%	Dec. 22
5	1.4.4	Concept study: recovery of nutrients	No pilot plant --> excluded from D1.2			
5	1.4.4	Solar-driven hydrothermal carbonisation demo plant	100%	100%	100%	May 22
6	1.3.3	AAT Karmiel		100%	100%	May 22
6	1.3.4	AAT + membrane filtration incl. AC Shafdan	90%	100%	100%	Aug 22
6	1.4.5	Recovery polyphenols (pilot system: adsorption column)	100%	100%	100%	Dec. 22
7	1.2.6	AnMBR + RO	50%	100%	100%	Aug 22
7	1.3.5	AnMBR + heat utilisation from its effluent		100%	100%	Aug 22
7	1.4.6	Recovery of struvite & ammonia via stripping	>100%	100%	100%	Sep 22
8	1.3.6	Feasibility study: heat recovery	No pilot plant --> excluded from D1.2			
8	1.4.7	Laboratory pilot: sulphur recovery	90%	100%	100%	Oct. 22
8	1.4.7	Industrial pilot: sulphur recovery		35%	0%	Aug 23
8	1.4.7	Feasibility study: metal recovery	No pilot plant --> excluded from D1.2			
9	1.2.7	Novel UF membrane		100%	100%	Jun 21
9	1.3.7	Joint control system	No pilot plant --> excluded from D1.2			
9	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 further updated every three months until every pilot plant will be operational. Those results will then be reported in the best practice guidelines (D1.3, D1.4 and D1.5).

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

4. Literature references

European Commission (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal COM/20197640 final (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640) accessed on Feb. 8th 2022.

European Commission (2020). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. A new Circular Economy Action Plan for a cleaner and more competitive Europe COM/2020/98 (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN) accessed on Apr. 11th 2022.

EU (2018/2001) Directive of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001&qid=1630937219623) accessed on Feb. 8th 2022

EU (2019/1009) Regulation of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R1009) accessed on Feb. 8th 2022

EU (2020/741) Regulation on minimum requirements for water reuse (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN) accessed on Feb. 8th 2022

Kleyböcker, A., Bruni, C., Naves Arnaldos, A., Casas Garriga, S., Fatone, F., van den Broeke, J., Iossifidis, D., Gimenez Lorang, A., Sabbah, I., Pidou, M., Reguer, A., Lundgaard, L., Bendix Larsen, S. (2021a). Assessment of baseline conditions for all case studies. D1.1 ULTIMATE project (GA 869318).

Kleyböcker, A., Naves Arnaldos, A., Bruni, C., Fatone, F. (2021b). Technology Evidence Base Concept and Integration. D1.6 ULTIMATE project (GA 869318).

Kleyböcker, A., Naves Arnaldos, A., Bruni, C. (2022). Lessons learned from synergy workshops. D1.8 ULTIMATE project (GA 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