PIONEER_STP

The Potential of Innovative Technologies to Improve Sustainability of Sewage Treatment Plants

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Water JPI
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CONSORTIUM DESCRIPTION

ACRONYM	TOPIC	Coordination	Partners
Pioneer STP	**I**		
The Potential of Innovative Technologies to Improve Sustainability of Sewage Treatment Plants		**innovative technologies; integration; wastwater treatment; greenhouse gases; energy; nutrients; optimization; plant-wide modelling**	

PRINCIPAL INVESTIGATOR	INSTITUTION	COUNTRY
Juan M. Lema	**University of Santiago de Compostela**	**Spain**
Francesco Fatone	University of Verona	Italy
Gürkan Sin	Technical University of Denmark	Denmark
Elzbieta Plaza	Royal Institute of Technology	Sweden
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State-of-the-art

- Sewage treatment plants (STP) are still mainly based on the Activated Sludge (AS) process, discovered 100 years ago.
- Unable to cope with the current societal challenges and legal requirements in wastewater treatment (WWT).
- The birth of a growing number of technological initiatives targeted WWT innovation.
- New targets as the recovery of resources, the production of effluents suitable for reuse (e.g. minimising the concentration of emerging pollutants (EPs)) and the reduction in energy consumption, sludge surplus and environmental impacts.
- How to consider all of them from a holistic point of view?

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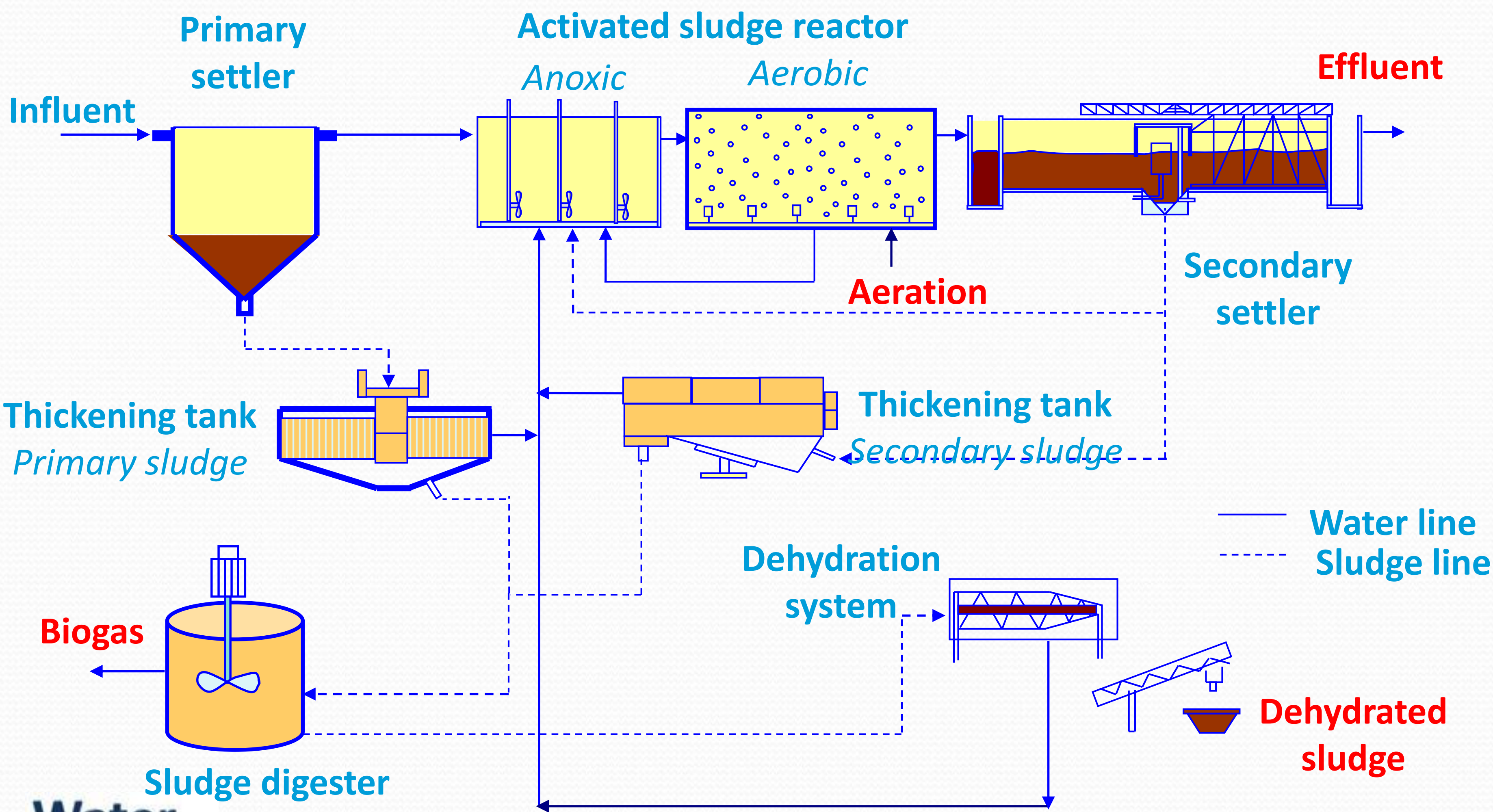
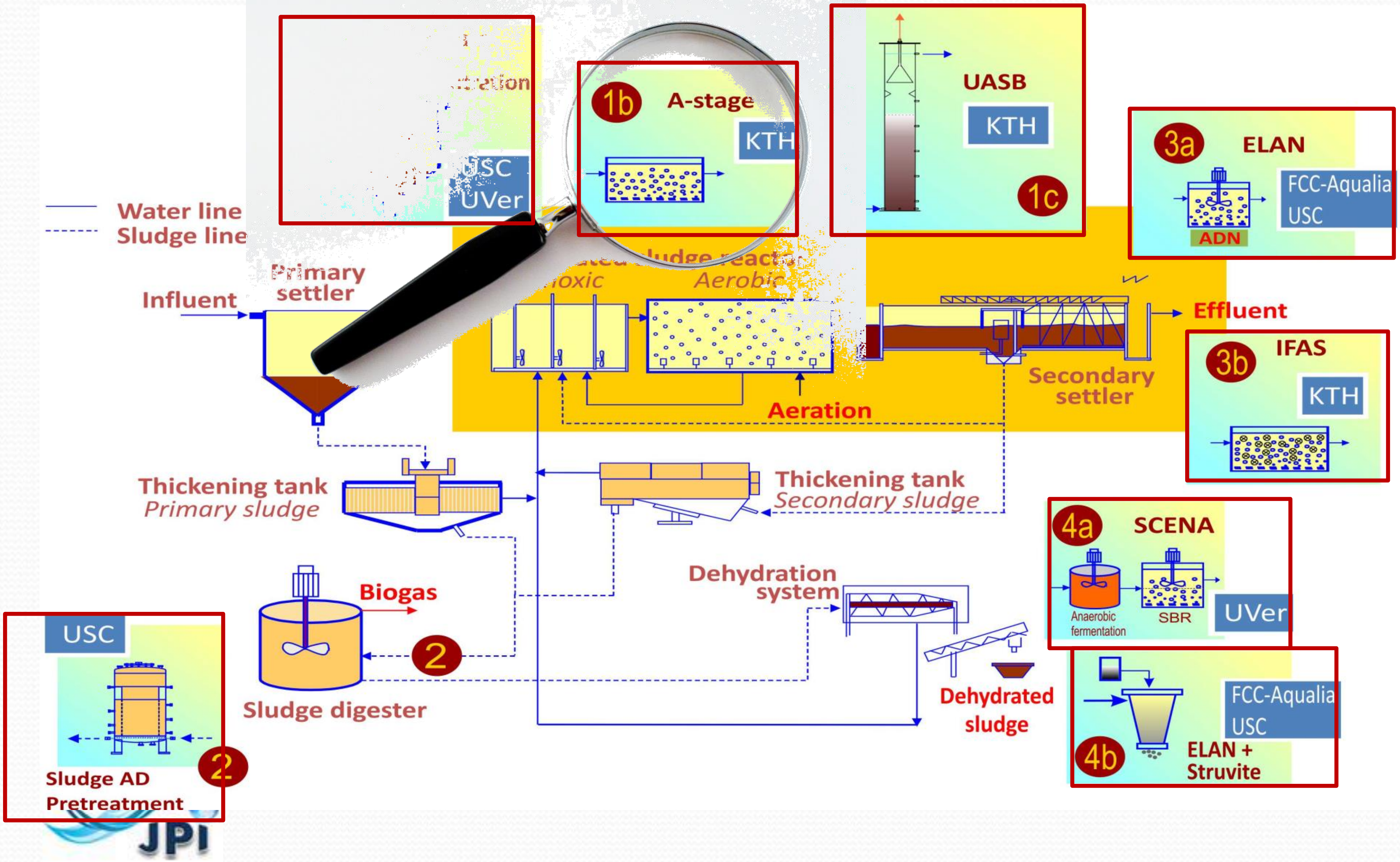
The Pioneer_STP strategy

- Development of innovative technologies for the treatment of wastewater, sludge and centrate.
- Characterization under a multicriteria perspective (design and operation, effluent quality, emissions, removal efficiency, costs, energy, etc.).
- Evaluation of the impact of integrating these technologies within the global plant layout.
- Optimization of the STP taking into account the strong interdependencies between the different streams.
- Holistic assessment (environmental, economic, energetic, risk).

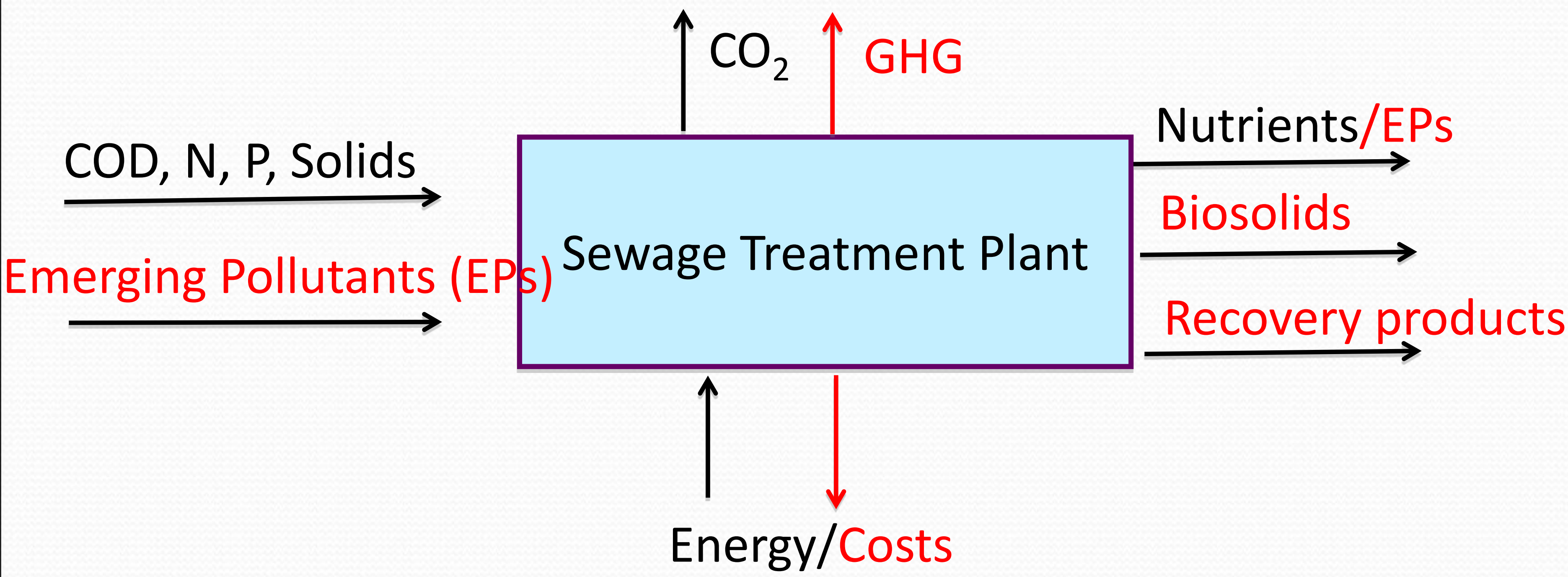
The Pioneer_STP strategy



The Pioneer_STP strategy



The Pioneer_STP strategy



Objectives

The ***Main Objective*** is to assess the impact of innovative units (nowadays at lab- or pilot-scale or in their early stages of industrial implementation) on the global plant efficiency and sustainability, taking into account nutrients, energy, Emerging Pollutants (EPs), greenhouse gases (GHGs) and cost/benefit balances.

Sub-Objectives

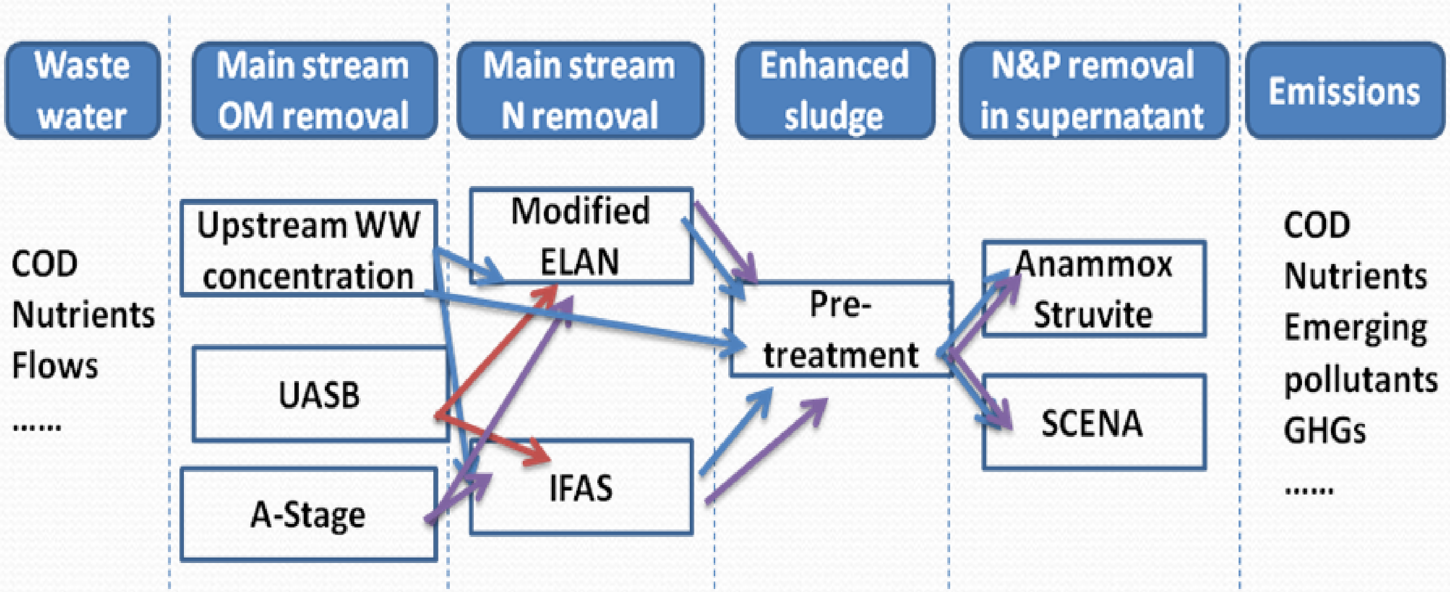
1. Develop 4 Unit Technological Solutions (UTS), two of them focused on energy recovery from valuable organic matter (UTS1&2) and two on nutrients removal/recovery (UTS3&4).
2. Combine the UTS into different plant layouts (using a superstructure-based optimization framework)
3. Assess the STP in terms of technical, environmental, energetic and economical aspects
4. Optimize the STP by modelling and simulation

Unit Technological Solutions

Position in plant layout	Technology	Main Target
Pre-Concentration Step	- Upstream wastewater concentration - High rate activated sludge (HRAS) - Anaerobic Treatment	Improve Energy balance - ↓ organic load in the water line by ↑ sludge production - Energy recovery in the water line
Sludge Line	Thermal pre-treatment	↑ Energy production during sludge Anaerobic Digestion
Mainstream Water Line	- Modified ELAN process - IFAS anammox	- N removal - ↓ Oxygen demand
Centrate from the AD	- Via nitrite N removal and P hyper-accumulation (SCENA) - ELAN followed by struvite precipitation	- N removal - P recovery

Process integration

Superstructure based optimization framework

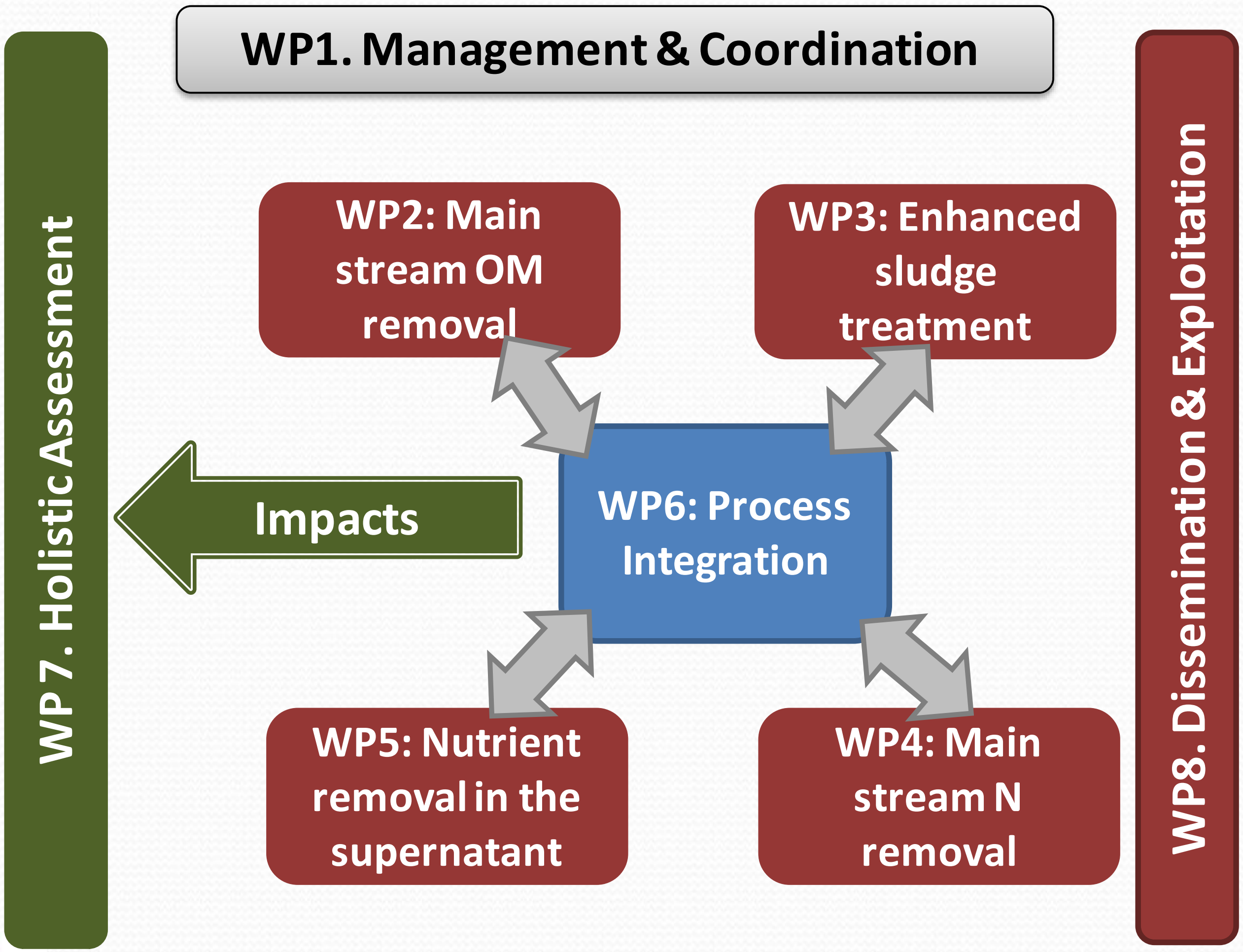


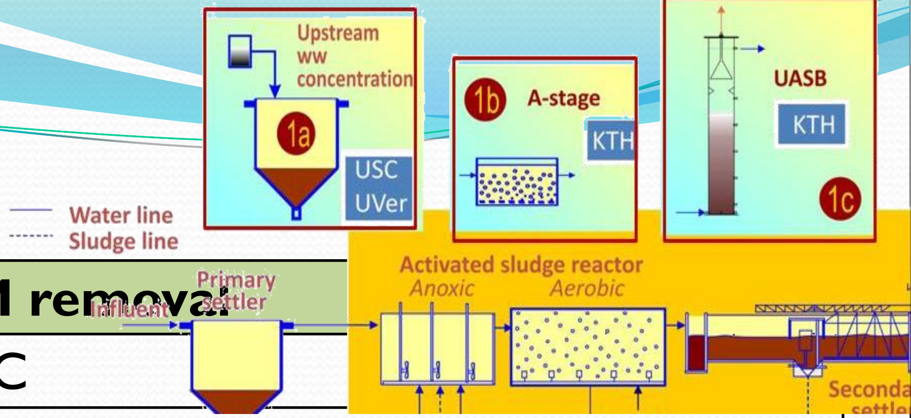
a) A database containing information on performance and economics of treatment units and optimization problem solved for different objective function formulations (economics, environmental, etc.)

b) The process design solution will be further optimized by using a dynamic plant wide modelling platform (PWM).

c) This will provide the data for assessing Risks and Environmental and Energetic impacts (LCA, RA, LCC)

Work Plan


WP1. Management & Coordination
WP 7. Holistic Assessment
WP2: Main stream OM removal
WP3: Enhanced sludge treatment
Impacts
WP6: Process Integration
WP5: Nutrient removal in the supernatant
WP4: Main stream N removal
WP8. Dissemination & Exploitation



WP2	**M1 to M24**	**Main stream OM removal**
Partners Involved		**UNIVR**, KTH, USC

Objectives: To enhance OM removal in the mainstream in order to promote autotrophic nitrogen removal in WP4 and increase the energy balance

Task 2.1 (USC, UNIVR months 1-18) Upstream wastewater concentration

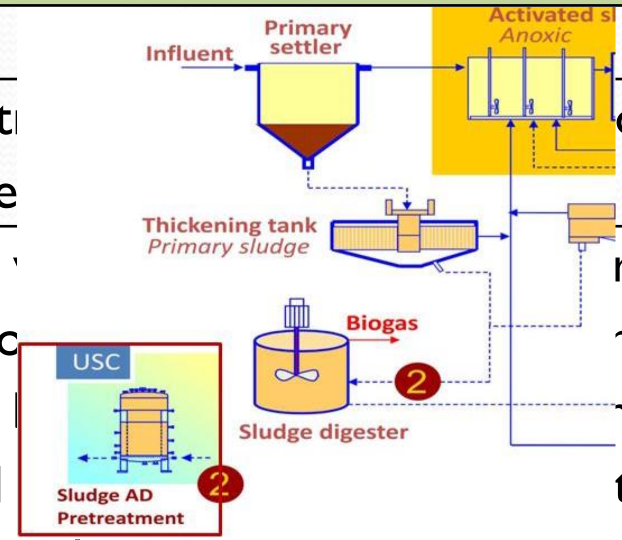
- *Chemically enhanced coagulation-precipitation* (cationic polymers, metal coagulants)
- *Rotating belt dynamic filter* with a fine mesh size after the head pumping station of the STP of Carbonera (Italy) to remove more than 50% of the total suspended solids.

Task 2.2 (KTH months 1-24) A-stage and UASB

OM removal from municipal wastewater in the mainstream is evaluated in an *UASB* reactor and also in a high rate activated sludge reactor *(HRAS)* working at a short SRT. The latter will increase the amount of OM available for biogas production in the sludge line while the first will produce the biogas directly in the mainstream.

WP3	M7 to M24	Enhanced sludge treatment
Partners Involved		**USC**

Objectives: To evaluate the effect of thermal pre-t of sludge treatment and on digested sludge and centrate



The UTS implemented in WP2, 4 & 5, will generate ry and secondary) that will be treated by AD. Our appro ng a link between the sludge characteristics produced ne efficiency of AD in terms of biogas production and te quality and (ii) to enhance sludge stabilization by thermal pre-treatment.

Task 3.1 (USC months 7-12) Single sludge characterization: batch biomethane potential (BMP) assays

Task 3.2 (USC months 10-12) Thermal pre-treatment

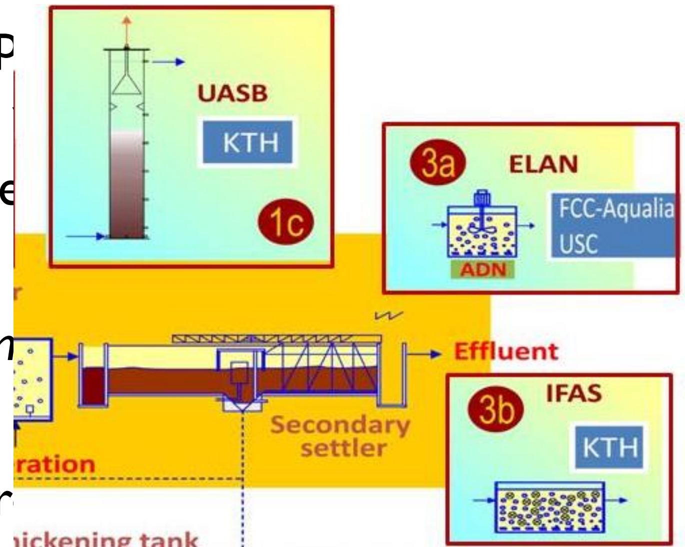
Task 3.3 (USC months 12-24) Continuous operation of AD pilot plant

WP4	**M11 to M28**	Main stream N removal
Partners Involved		**KTH,** Aqualia, USC

Objectives: To evaluate the Anammox bacterial consortium at ambient temperatures with regard to their N removal potential and stability

Task 4.1 (KTH months 11-28) Integrated fixed film activated sludge (IFAS)

Removal will be done in two separate p reactors (MBBR) of 200 L operated as IFAS mode equipped with variety of on-line measurements. One and the other to the HRAS described in task 2.2.



Task 4.2 (USC, Aqualia months 11-28) Anam r biomass (Modified ELAN®)

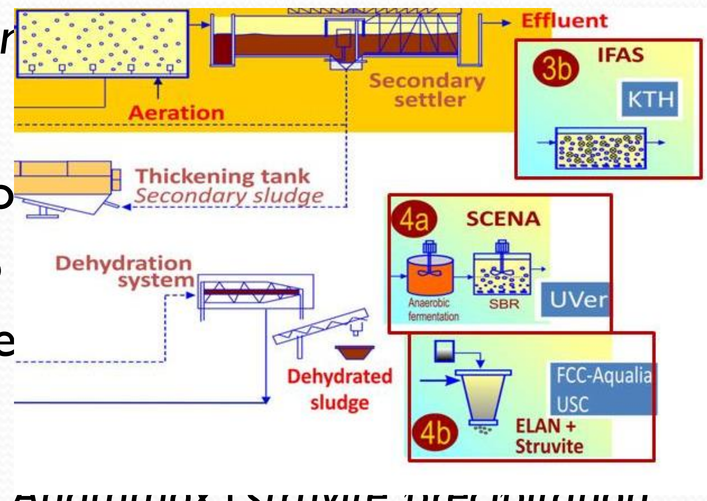
Partial nitrification (PN) and anammox pr d in two separated units to establish the best operational conditions for each process. Special attention will be paid to the selection of those conditions allowing the suppression of NOB activity. In the last 6 months both processes will be fed with the effluent from WP2 either in a single unit or in two units connected

WP5	M1 to M18	Nutrient removal in the supernatant
Partners Involved		**Aqualia,** UNIVR

Objectives: To evaluate the efficiency of nutrient removal in the centrate of AD by two different strategies

Description of Work

Task 5.1. (UNIVR months 1-18) Optir … *ation – short cut SBR operation*



The alkaline fermentation reacto … osic sludge separated in task 2.1 in order to … The sludge fermentation liquid and the sludge … a SBR (2.8 m^3) in order to remove N and P.

Task 5.2 (Aqualia, USC months 1-18) Anammox + struvite precipitation

A pilot scale ELAN® process will be operated treating the supernatant of the sludge anaerobic digester. EPs will be followed in the solid and liquid phases. Data from the full scale ELAN® plant will be also used for the evaluation.

<table>
<tr><td>WP6</td><td>M1 to MM30</td><td>Process Integration</td></tr>
<tr><td colspan="2">Partners Involved</td><td>DTU, USC</td></tr>
<tr><td colspan="3">Objectives: To develop a superstructure based optimization tool for generating new plant layouts, optimized and characterized by means of a plant-wide quantification tool, including mechanistic models for EPs and GHGs</td></tr>
<tr><td colspan="3">Task 6.1 (USC, DTU months 1-28) Data collection and analysis
Data from the previous UTS (WP2, 3, 4 & 5) including COD, N, P, GHGs and EP, energy consumption/production, use of reactants, etc.
Task 6.2 (DTU months 1-24) superstructure based optimization
(i) the definition of the design space, the description of each alternative in the superstructure using steady-state process stoichiometry model, (ii) the optimization for different objective function formulations
Task 6.3 (DTU months 1-30) Mechanistic modelling and plant wide simulation tool
The ASM will be used and extended for EP removal and N_2O and CO_2 production
The plant-wide model will be developed based on the Benchmark Simulation Model 2 and used to verify and further optimize the process concepts</td></tr>
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WP7	M19 to M36	Holistic assessment
Partners Involved		**USC**, DTU

Objectives: To confirm the feasibility of the different UTS to improve the sustainability of STPs.

Task 7.1 (USC months 18-30) Life Cycle Assessment (LCA)

Inventory tables will be prepared using the database obtained in WP6. To determine the overall environmental impacts as a result of the flows through the system, LCA integrates the environmental impact within relevant impact categories.

Task 7.2 (USC months 18-24) Environmental Risk Assessment (RA)

Inventory of effluent and sludge concentrations of the three EPs considered (diclofenac, 17-a ethinylestradiol, 17-b estradiol) analysed within WP2, 3, 4 &5 will be employed to perform the RA under both stream discharge and reuse scenarios.

Task 7.3 (DTU, USC months 25-32) Economic impacts(LCC)

The economic profiles from a Life Cycle perspective will be determined, including the representative life cycle stages.

Task 7.4 (DTU, USC months 30-36) Holistic evaluation: integration multicriteria indicators

A systematic approach for assessment of importance of weights on decision making function will be performed using sensitivity analysis as well as pare to front analysis.

Mobility plan

From \ To	USC	DTU	Aqualia	UNIVR	KTH
USC		Modelling sludge pre-treatment + AD (WP3→6)	Main stream Anammox up-scale (WP4; intersectoral)	Data gathering for assessment (WP7→WP5)	
DTU	Holistic assessment (WP6→7)				Modelling mainstream Anammox (WP6→4)
AQUALIA		Modelling Anammox side stream (WP2→6)			
UNIVR			SCENA vs. ELAN (WP5; intersectoral)		
KTH	IFAS after upstream conc. (WP4→WP2)				

Expected Impact

Scientific and Technological

- Development of new technologies for water, sludge and centrate treatment
- Integrate nutrients, energy, GHGs, EPs and cost/benefit balances within the entire STP

Economic

- STPs conceived as green factory for reducing pollution and recovering resources
- Incorporating the process economics into the optimization function

Expected Impact

Economic

- Decision support tool allowing to select the best plant layout in terms of <u>sustainability</u> fosters innovation and competitiveness of European water sector
- Strong collaboration <u>University-Industry</u>

Societal

- Generation of high quality and <u>safe waters</u> (conventional pollutants, emerging pollutants)
- Protecting <u>quality air</u> (reducing GHG emission)
- <u>Training</u> of water professionals able to tackle the interdisciplinary approach needed for designing/upgrading the STP of the future

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Expected Impact

Policy

- The EPs considered in this proposal are currently included in the watch list of priority substances of the WFD (diclofenac, 17-a ethinylestradiol, 17-b estradiol)
- Cutting GHG emissions under the Kyoto Protocol (WWT generates CO_2, CH_4 and N_2O)

Water JPI and European Research Area objectives

- JPI Water SRIA includes EP emissions with regards to developing safe water systems for citizens (pilot call 2013)
- Pioneer_STP combines basic and applied approaches (e.g. TRL 4-5 for low T Anammox; TRL 7 for SCENA and 8 for ELAN applied to centrate)
- Mobility plan to enhance cooperation and to maximize inter-disciplinary and inter-sectoral collaborations is drafted.

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