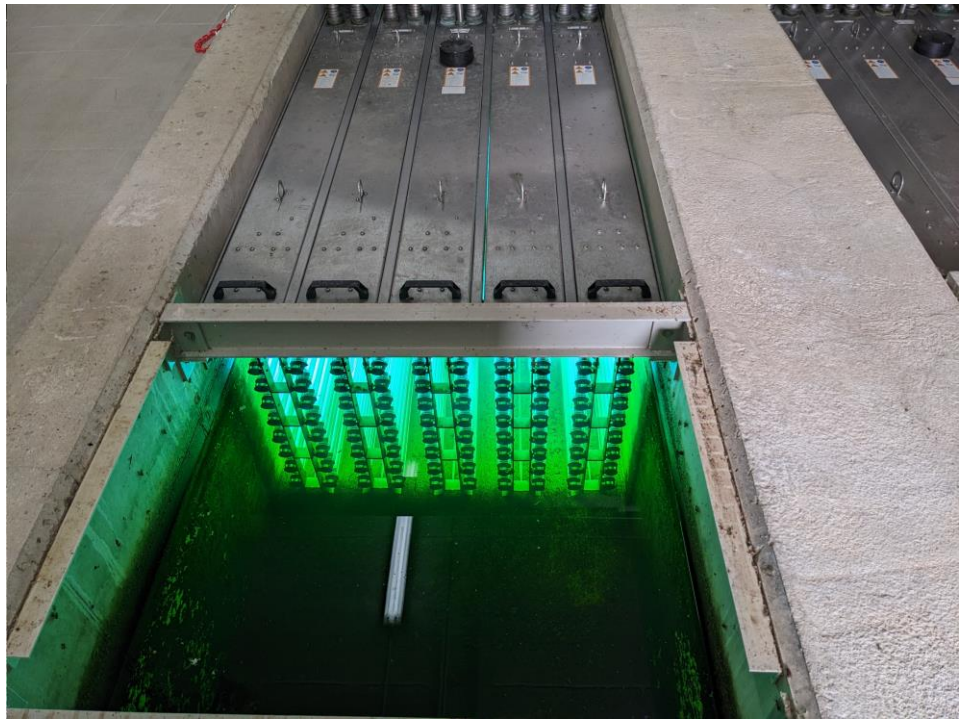
Improving energy efficiency in the tertiary treatment of Alguazas WWTP (Spain) by means of digital twin development based on Physics modelling

DTCONEDAR



https://doi.org/10.33774/coe-2023-1vjcw **ORCID:** https://orcid.org/0000-0002-0068-2123

Architectures for dependable digital twins

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This use case answers the question of how to develop a replicable architecture for development a digital twin in a waste water plant

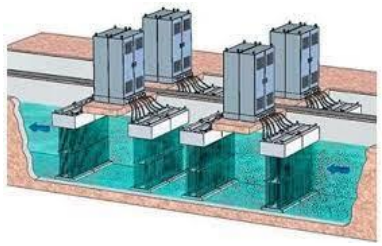
The basic idea is to develop the digital twin using the following elements:

- **Sensors and Data Acquisition:** Extract information from the waste water plant using the automation system. Different types of sensors are used to collect real-time data from the physical state: flowmeters, temperature and pressure probes, pH, conductivity, among others.
- **Communication Infrastructure:** Analyze the communication architecture of the waste water plant, from PLCs to SCADAs. Main industrial protocols are profibus, profinet, modbus, TCP/IP, OPC UA.
- **Data Storage and Management:** Real and synthetic data is stored in the database of the SCADA. The information is accessible from different users and in different formats.
- **Analytics and Modeling:** The analysis and models developed in the project are employed to derive insights from the collected data.
- **Visualization and User Interface:** An intuitive interface for industrial operators and engineers should be created to interact with the digital twin. In this project, a new faceplate was created in the SCADA of the plant.

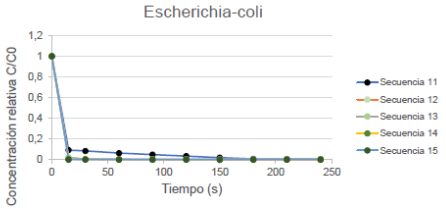
Project Objectives

Main Objective: **Reduce energy consumption** in the tertiary treatment of a WWTP.

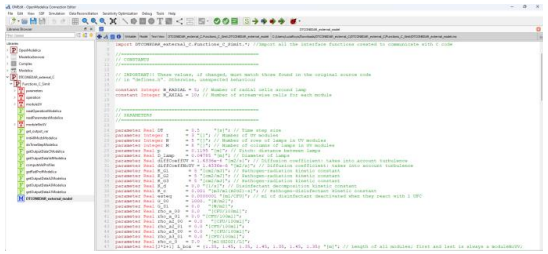
- Develop a **physics-based digital twin** using a fast-response reduced-order simulator.
- Define a **compartment model** for the simulator to realistically contemplate **hydraulic operation based on CFD**.
- Connect the fast response simulator to **a SCADA system** & continuously **monitorize** the full-scale disinfection process using the digital twin.
- Characterize **the disinfection reaction kinetics** in tertiary treatment by experimental measurements and **implement the disinfection equations** in the simulation model to monitor key species in treated water reuse.
- Develop an integrated SCADA tool to help the operator **taking better decision reducing the number of hours the UV system is working**.



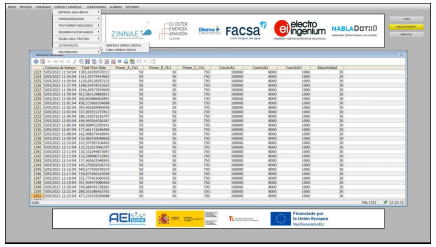
Hydrodynamic Simulation of the System: CFD.



Characterization of the kinetics of pathogen degradation.



Real time calculation: Compartment model



PLC integration & SCADA visualization

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Project WP & Partners

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WP1: Project coordination

WP3: Experimental measurements in the lab and in field

DIAMA

WP2: CFD Process Simulation

WP4: Development of compartmental model

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HYDRENS HYDRODYNAMIC & ENVIRONMENTAL SERVICES

NABLADOT::() INGENIERÍA COMPUTACIONAL DE FLUIDOS

WP5: New control strategy & SCADA integration

ei electro ingenium INGENIERIA Y GESTION DE PROYECTOS INDUSTRIALES

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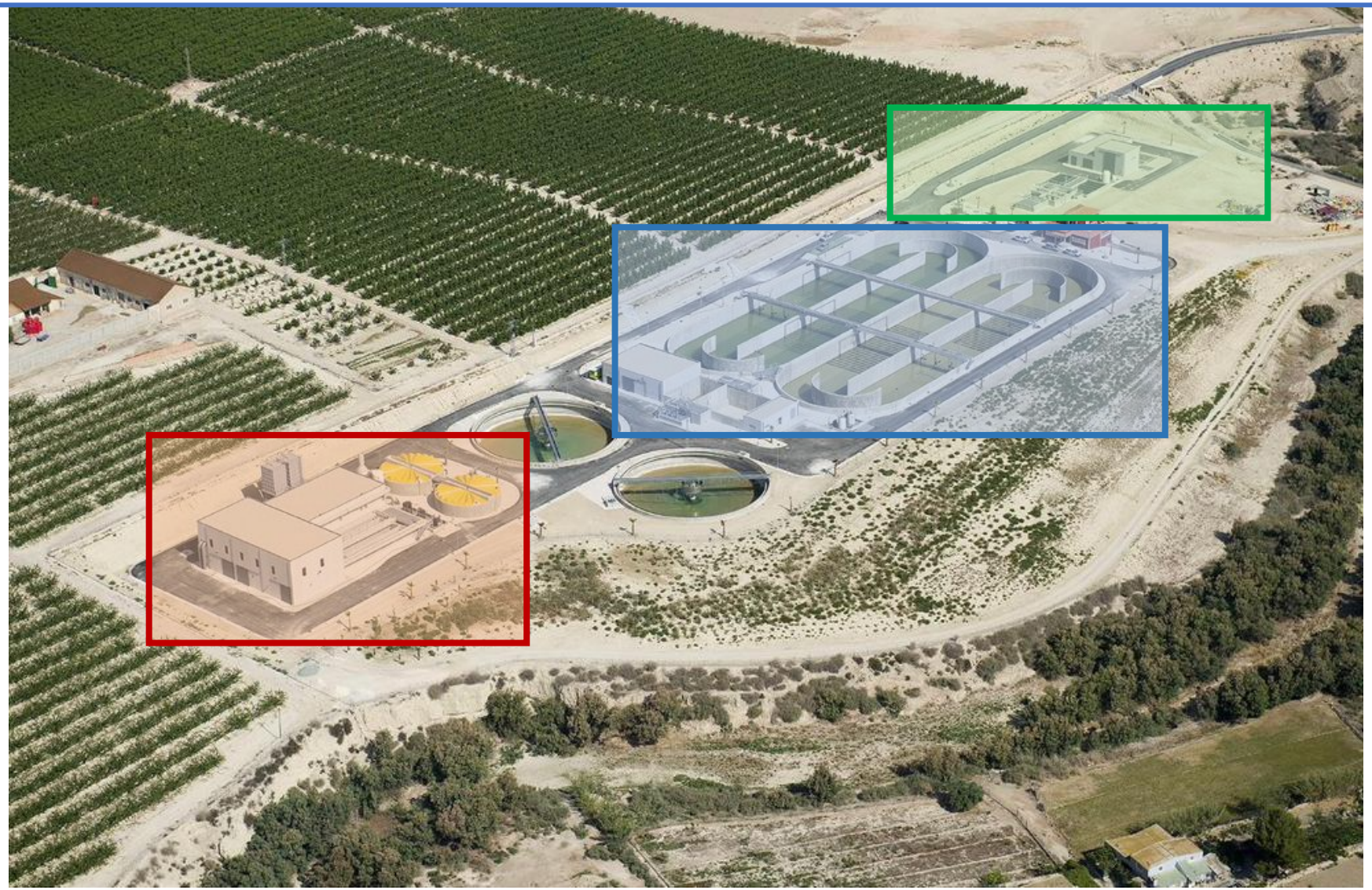
WWP layout

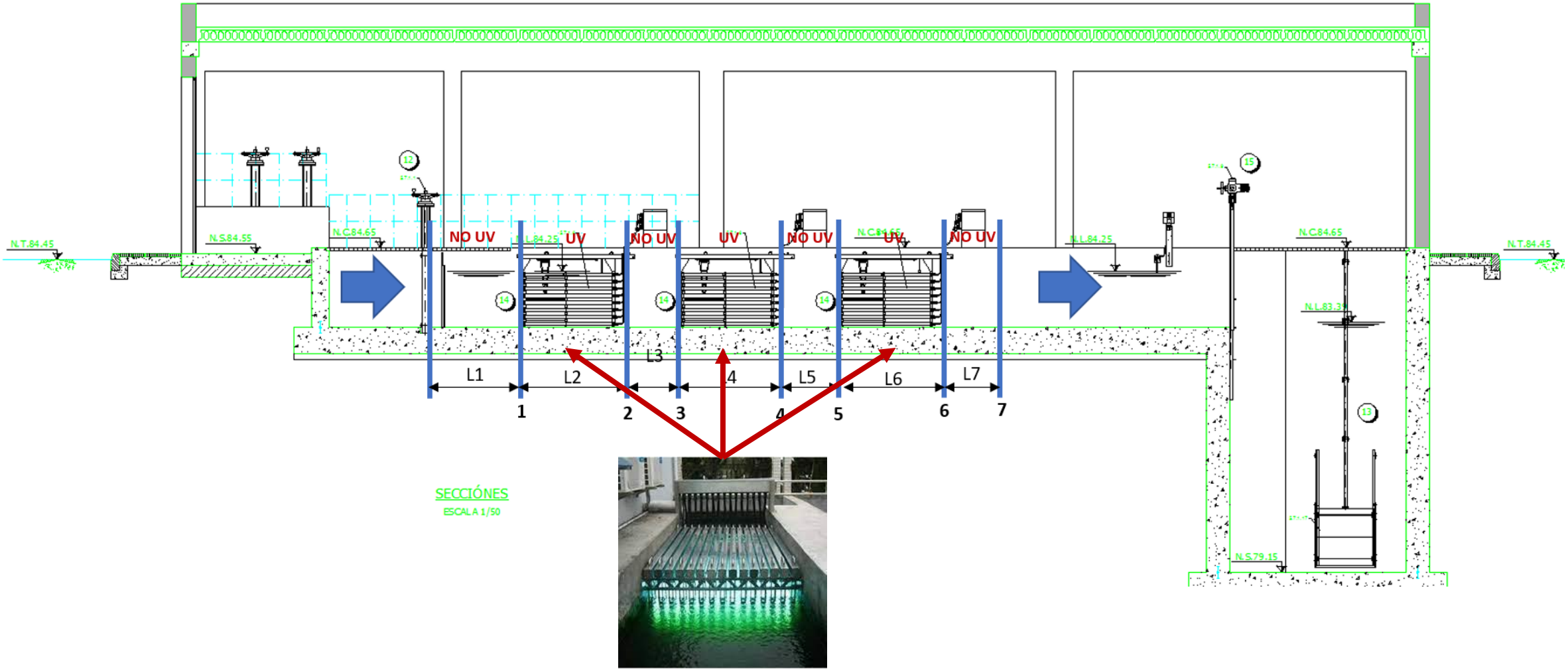


Tertiary Treatment

Secondary Treatment

Primary Treatment

WWP layout: Tertiary Treatment



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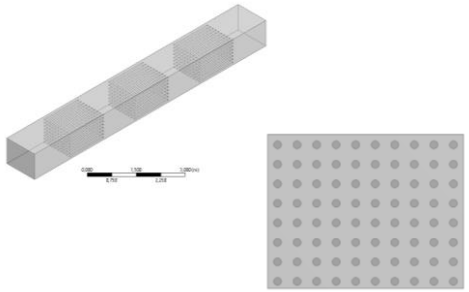
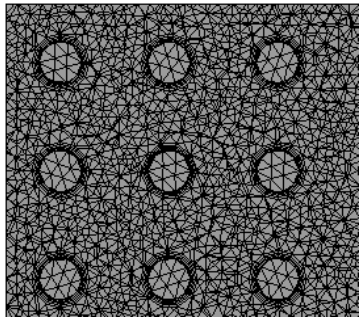
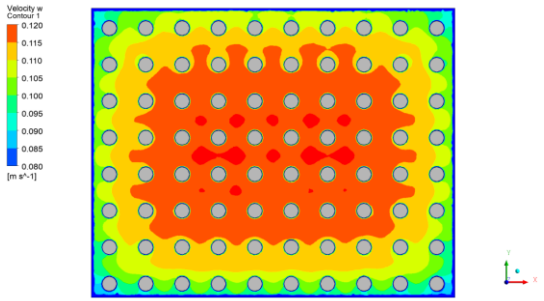
Project methodology: WP2 PROCESS SIMULATION

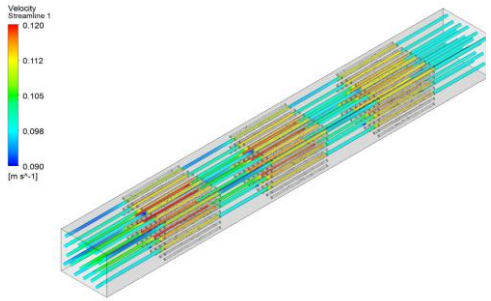
Virtual representation of the processes that are developed at a real level: CFD model

Geometry → Mesh → Boundary Conditions (Hydrodynamics, radiation, disinfection) → Results



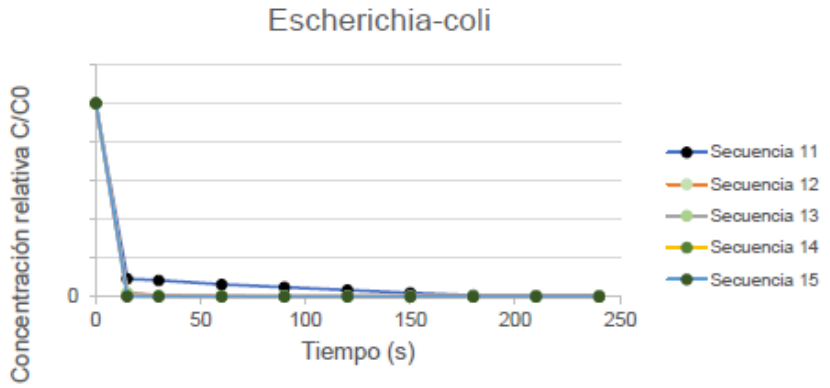






DIAMA Project methodology: WP3 EXPERIMENTAL MEASUREMENTS

Laboratory tests to develop the CFD model, calibrate it, validate it at full scale and monitor disinfection performance through analytical control of water quality in WWTPs. It will also define the disinfection rate of pathogens for different doses of UV radiation and H2O2.



Tests with:

- Total coliforms
- Escherichia coli
- Clostridium perfringens

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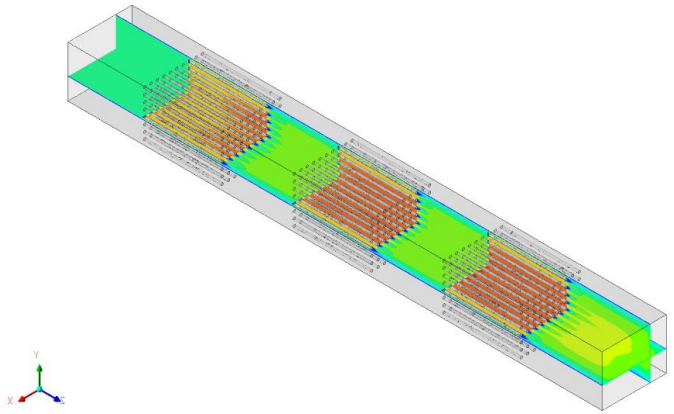
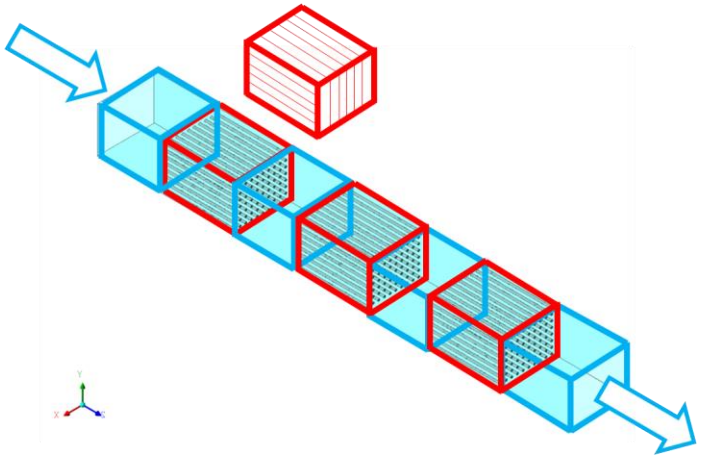
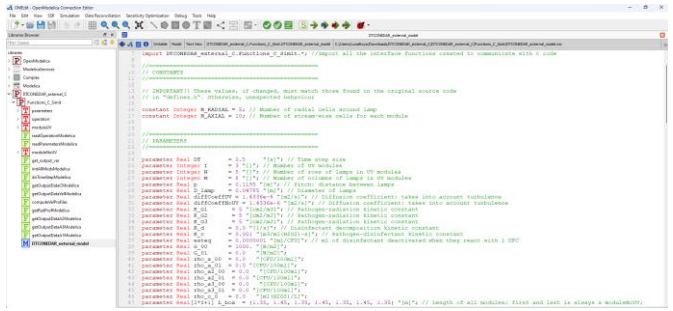
Project methodology: WP4 DEVELOPMENT OF DIGITAL TWIN

Data from CFD &experiments → Reduced physics model → Integrate into control software (FMI/Modelica)







Process data used to guide development of reduced model (velocity profiles, radiation profiles, disinfection kinetics...)

Reduced model (in C) still solves physical conservation laws, but simplifies details (geometry, mainly) to ensure real-time calculations and accurate results

C solver developed earlier is used by OpenModelica model. OpenModelica converts it into FMI standard, to be integrated in control software model

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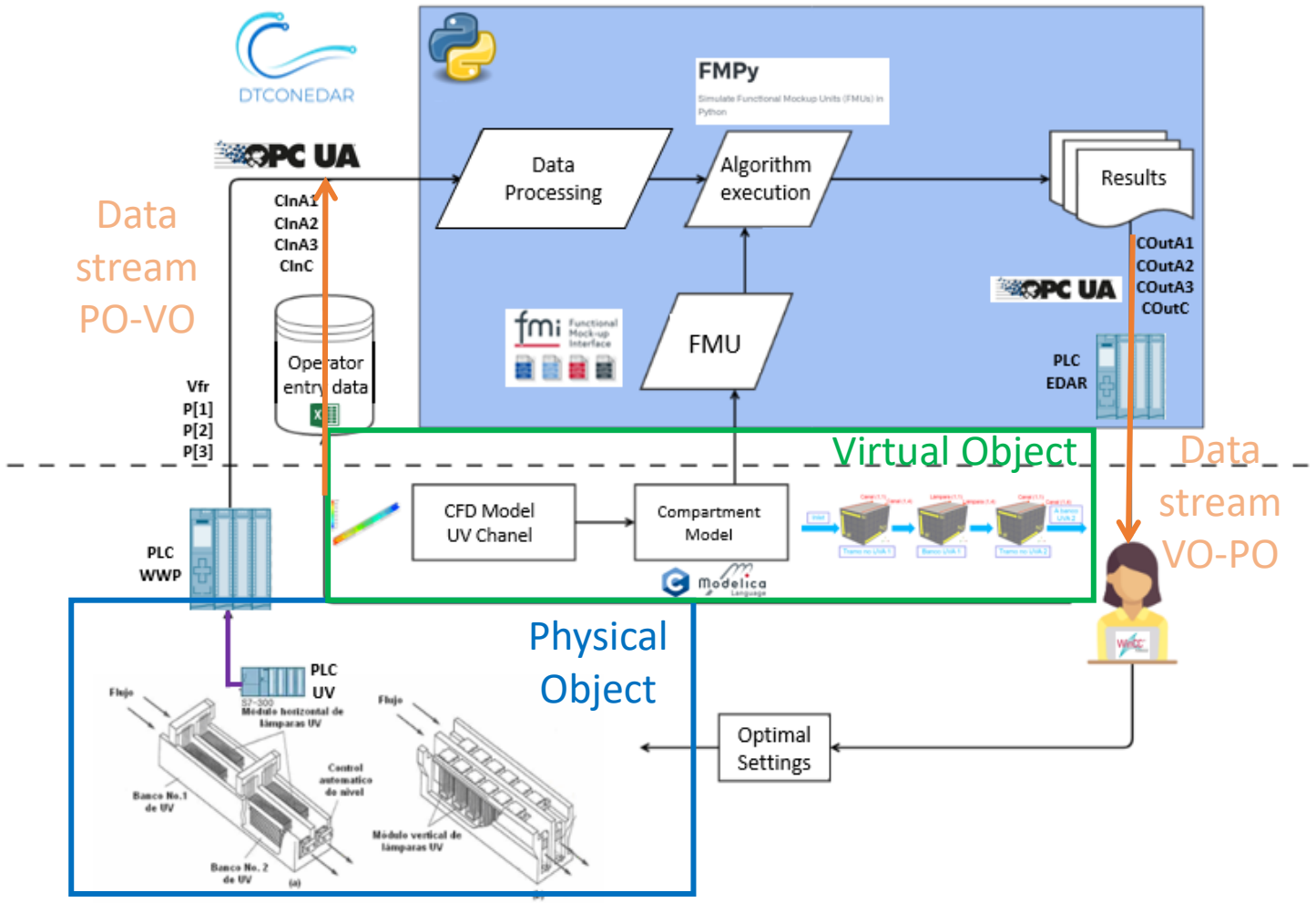
Project methodology: WP5 NEW CONTROL SYSTEM



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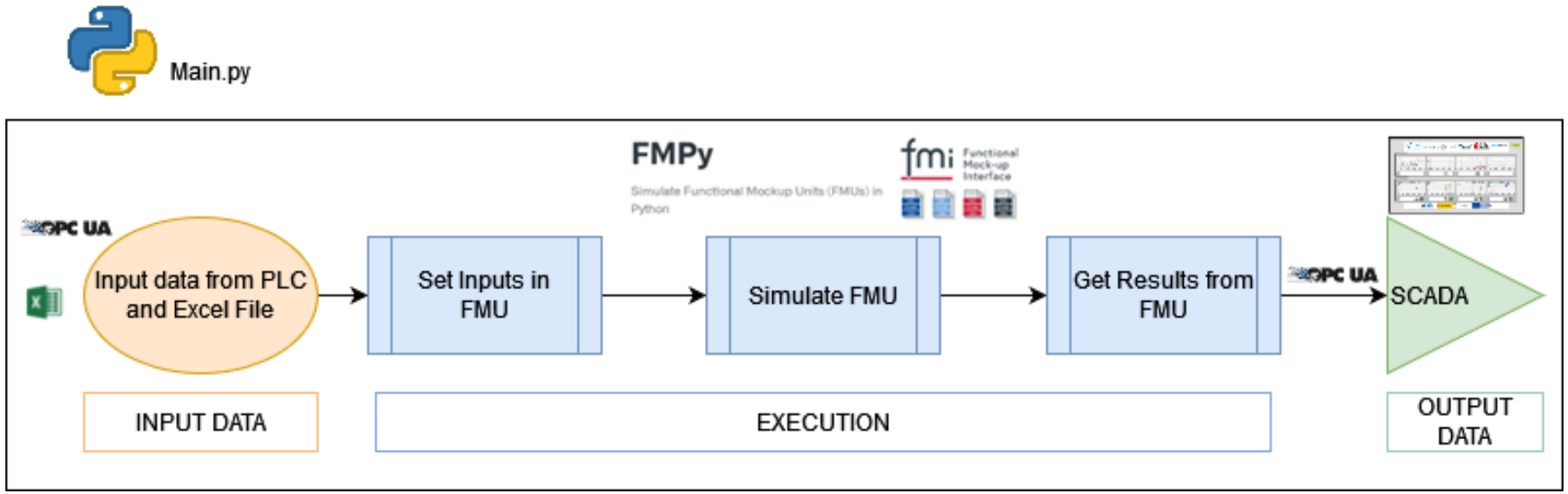
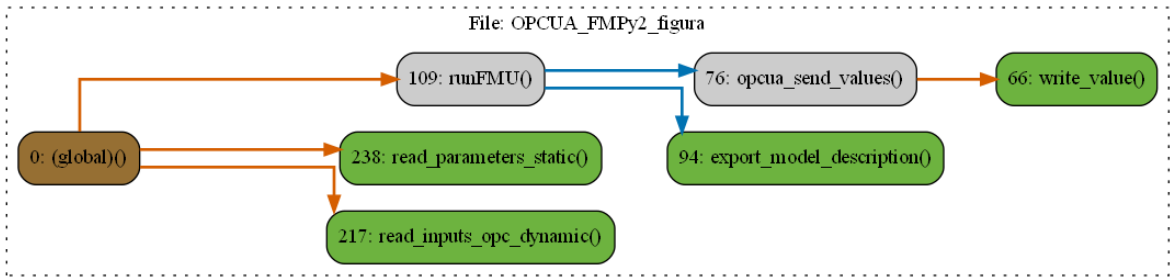
Project methodology: WP5 NEW CONTROL SYSTEM





Code2flow Legend	
Regular function	
Trunk function (nothing calls this)	
Leaf function (this calls nothing else)	
Function call	→

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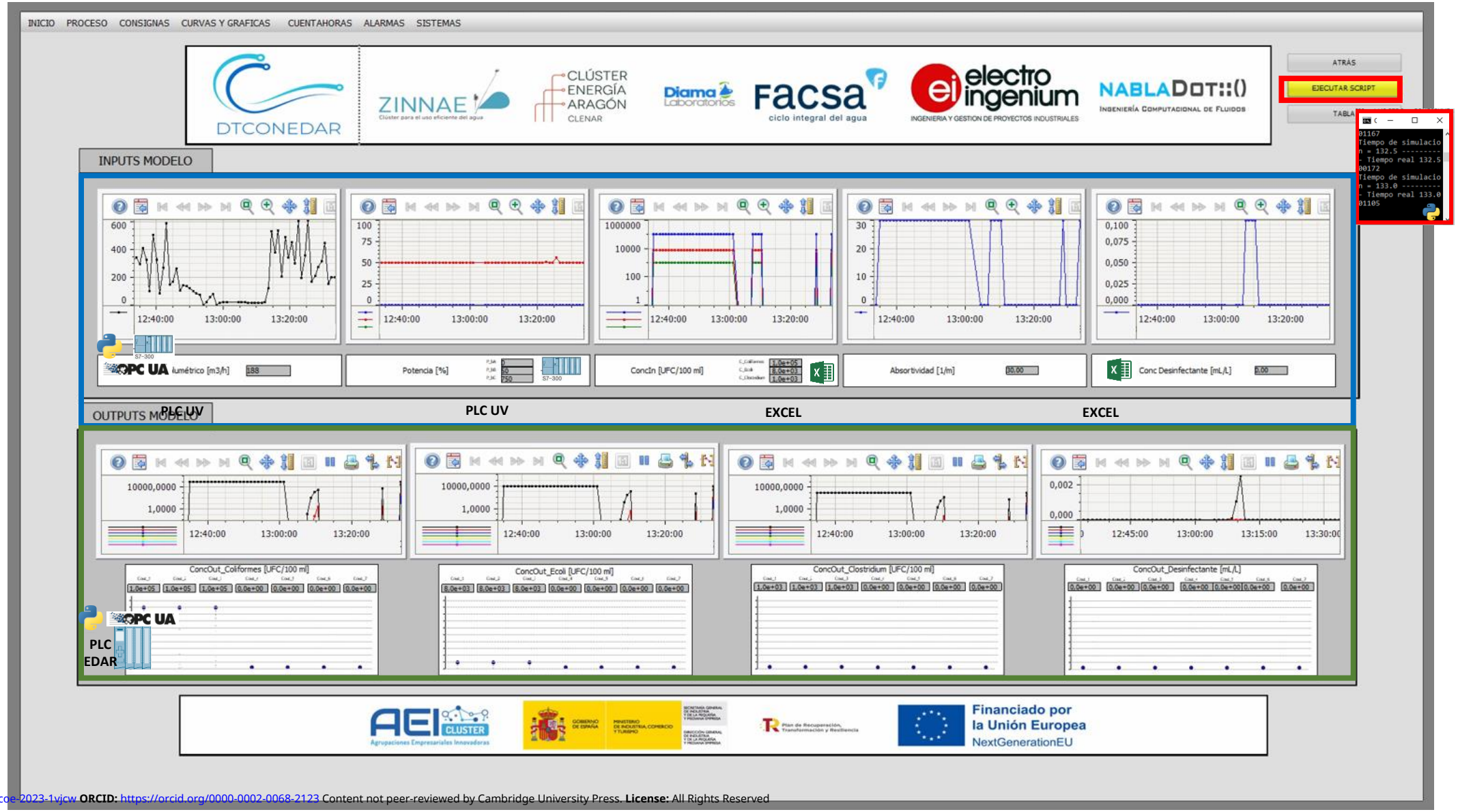
DTCONEDAR: Solution in the tertiary process



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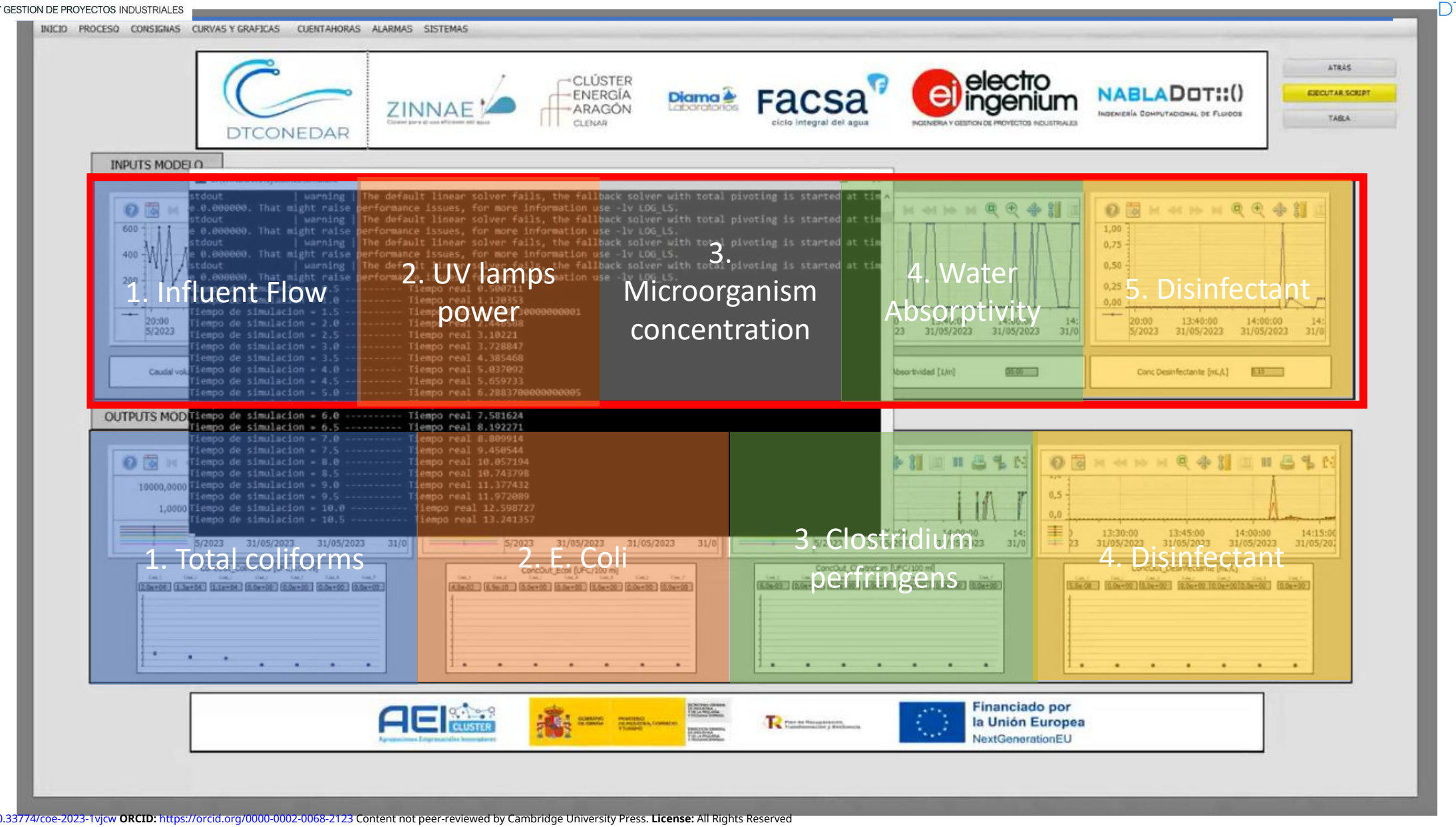
DTCONEDAR: Solution in the tertiary process



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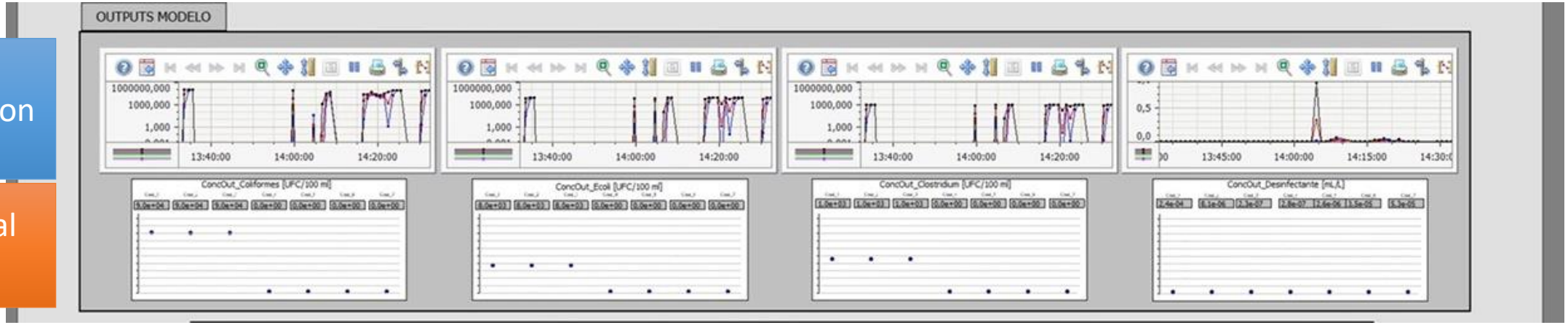
DTCONEDAR: Solution in the tertiary process

Evolution of the concentration of disinfectant and microorganisms along the channel:

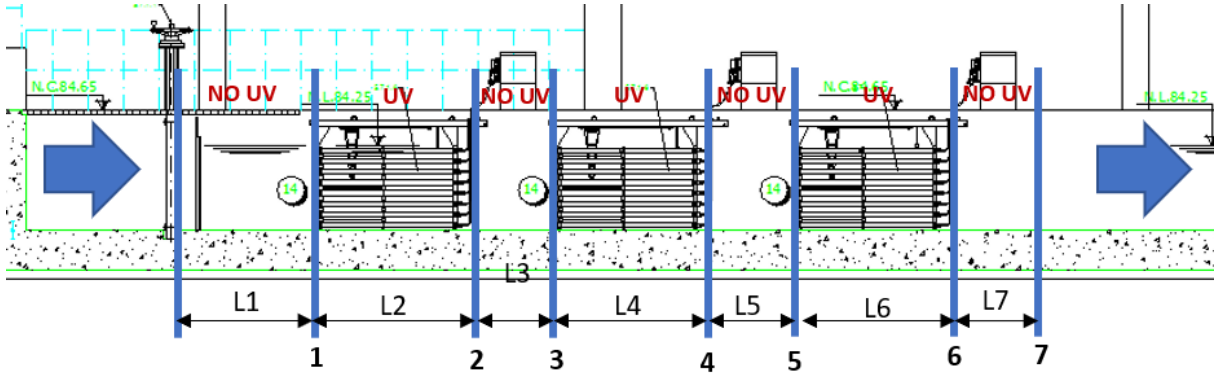
1. Time evolution
2. Longitudinal evolution in the last time of the simulation

1. Time evolution

2. Longitudinal evolution



There are 7 different locations in both representations:



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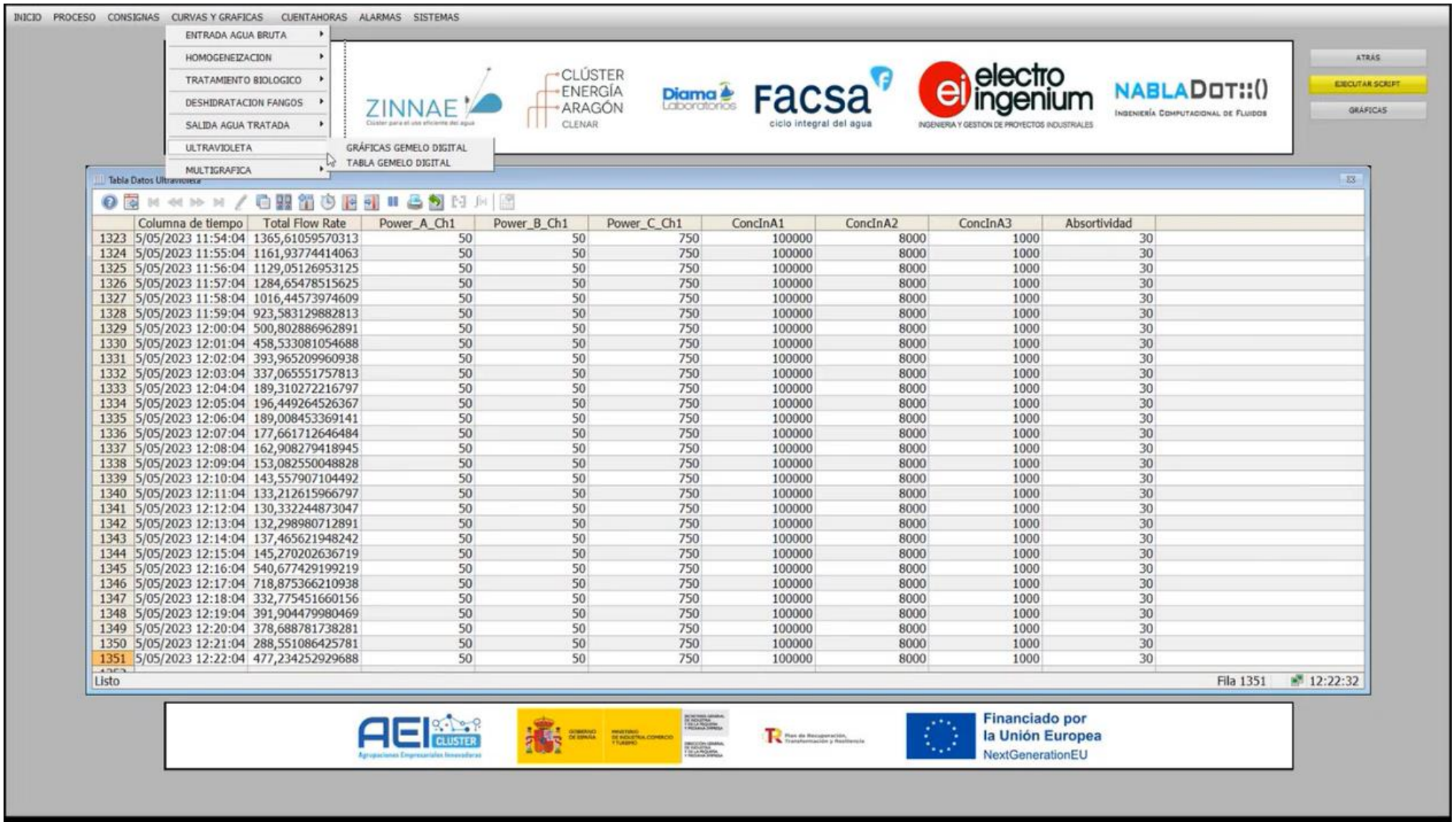
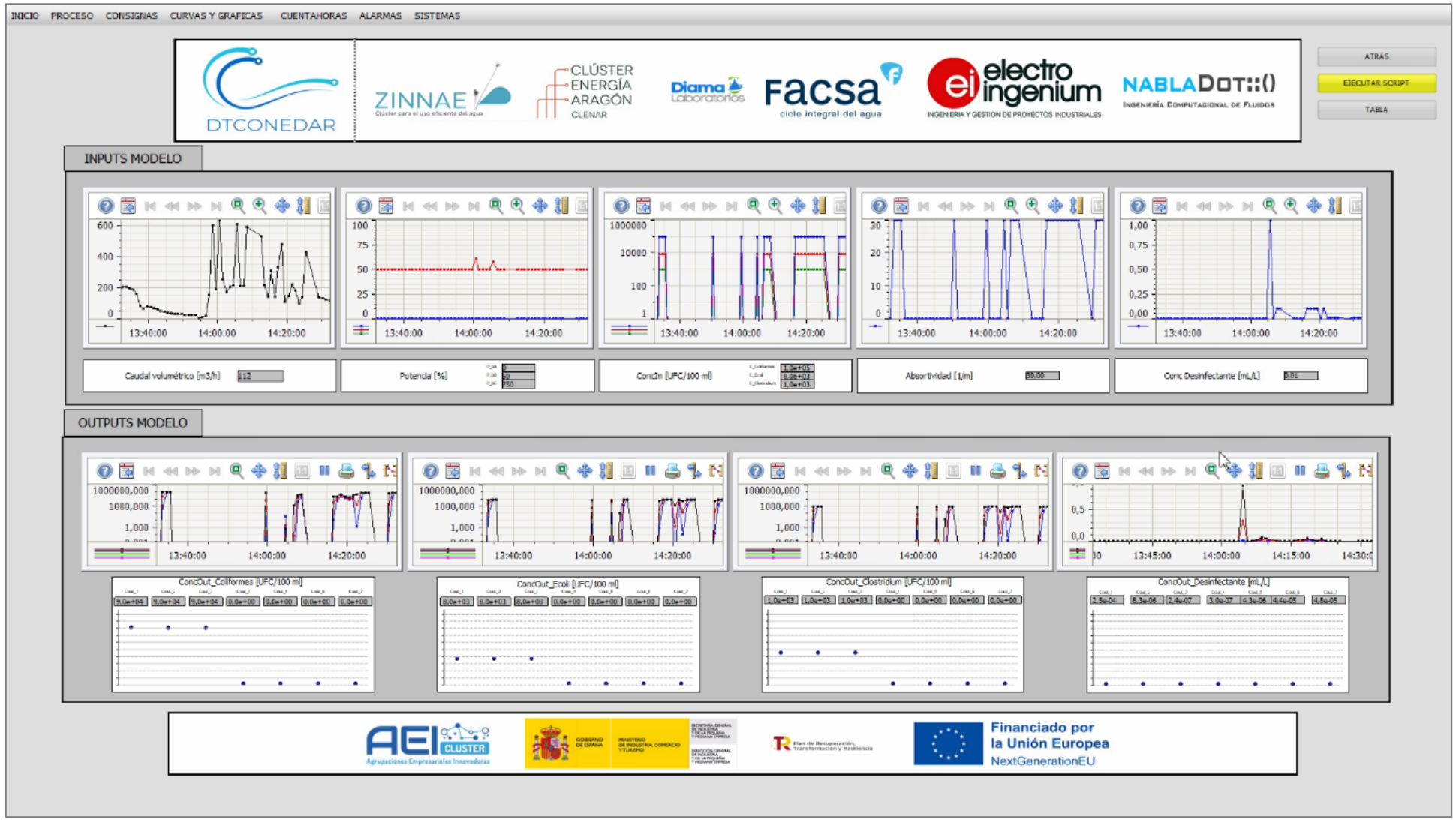


	Columna de tiempo	Total Flow Rate	Power_A_Ch1	Power_B_Ch1	Power_C_Ch1	ConcInA1	ConcInA2	ConcInA3	Absortividad
1323	5/05/2023 11:54:04	1365,61059570313	50	50	750	100000	8000	1000	30
1324	5/05/2023 11:55:04	1161,93774414063	50	50	750	100000	8000	1000	30
1325	5/05/2023 11:56:04	1129,05126953125	50	50	750	100000	8000	1000	30
1326	5/05/2023 11:57:04	1284,65478515625	50	50	750	100000	8000	1000	30
1327	5/05/2023 11:58:04	1016,44573974609	50	50	750	100000	8000	1000	30
1328	5/05/2023 11:59:04	923,583129882813	50	50	750	100000	8000	1000	30
1329	5/05/2023 12:00:04	500,802886962891	50	50	750	100000	8000	1000	30
1330	5/05/2023 12:01:04	458,533081054688	50	50	750	100000	8000	1000	30
1331	5/05/2023 12:02:04	393,965209960938	50	50	750	100000	8000	1000	30
1332	5/05/2023 12:03:04	337,065551757813	50	50	750	100000	8000	1000	30
1333	5/05/2023 12:04:04	189,310272216797	50	50	750	100000	8000	1000	30
1334	5/05/2023 12:05:04	196,449264526367	50	50	750	100000	8000	1000	30
1335	5/05/2023 12:06:04	189,008453369141	50	50	750	100000	8000	1000	30
1336	5/05/2023 12:07:04	177,661712646484	50	50	750	100000	8000	1000	30
1337	5/05/2023 12:08:04	162,908279418945	50	50	750	100000	8000	1000	30
1338	5/05/2023 12:09:04	153,082550048828	50	50	750	100000	8000	1000	30
1339	5/05/2023 12:10:04	143,557907104492	50	50	750	100000	8000	1000	30
1340	5/05/2023 12:11:04	133,212615966797	50	50	750	100000	8000	1000	30
1341	5/05/2023 12:12:04	130,332244873047	50	50	750	100000	8000	1000	30
1342	5/05/2023 12:13:04	132,298980712891	50	50	750	100000	8000	1000	30
1343	5/05/2023 12:14:04	137,465621948242	50	50	750	100000	8000	1000	30
1344	5/05/2023 12:15:04	145,270202636719	50	50	750	100000	8000	1000	30
1345	5/05/2023 12:16:04	540,677429199219	50	50	750	100000	8000	1000	30
1346	5/05/2023 12:17:04	718,875366210938	50	50	750	100000	8000	1000	30
1347	5/05/2023 12:18:04	332,775451660156	50	50	750	100000	8000	1000	30
1348	5/05/2023 12:19:04	391,904479980469	50	50	750	100000	8000	1000	30
1349	5/05/2023 12:20:04	378,688781738281	50	50	750	100000	8000	1000	30
1350	5/05/2023 12:21:04	288,551086425781	50	50	750	100000	8000	1000	30
1351	5/05/2023 12:22:04	477,234252929688	50	50	750	100000	8000	1000	30

DTCONEDAR: Solution in the tertiary process



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Conclusions & Future Works

Four of the main aspects of DTCONEDAR's digital twin are:

- The high level of detail of the models to be implemented (hydraulic behavior + specific reactions)
- The development of compartment models, calculated in real time providing online information for plant control operator.
- The consideration of different types of pathogens.
- The integration of a DT in a real SCADA system to assist in the decision making process.

- Future Works (2nd part): Development of digital twin of the secondary treatment

References

More information of the DTCONEDAR's project can be found in the following links:

- General Information (Phase 1): https://zinnae.org/proyectos/dtconedar/
- General Information (Phase 2): https://zinnae.org/proyectos/dtconedar-fase2/
- Tecnoacua: https://www.tecnoaqua.es/noticias/20221213/fascsa-proyecto-dtconedar-gemelo-digital-hibrido-estacion-depuradora-aguas-residuale
- Local Magazine: https://redaccion.camarazaragoza.com/laboratorios-diama-participa-en-el-gran-proyecto-internacional-que-transformara-digitalmente-las-edar/?utm_source=Publicate&utm_medium=URL&utm_content=...&utm_campaign=Publication+711