



Advancing Sustainability of Process Industries through Digital and Circular Water Use Innovations

**Materializing circular water use, fostering awareness in resource efficiency, and delivering innovative solutions for a Water-Smart Society**

## AquaSPICE Info-Day Event, Chania

Thalia KARKOU

Technical University of Crete (TUC)  
Industrial and Digital Innovations Research Group (Indigo)



# AquaSPICE At a Glance

*Advancing Sustainability of Process Industries  
through Digital and Circular Water Use Innovations*

<https://aquaspice.eu/>

**Funded under** INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies - Advanced manufacturing and processing

**Topic** CE-SPIRE-07-2020 - Preserving fresh water: recycling industrial waters industry

**Coordinator:** Rheinisch-Westfaelische Technische Hochschule Aachen, Prof. Thomas Wintgens

**Technical Coordinator:** Technical University of Crete, Assoc. Prof. George Arampatzis

AquaSPICE promotes the **circular use of water** in **Process Industry** and fosters awareness in resource-efficiency. It provides compact solutions such as **water treatment and reuse technologies** and **recycling practices**, while developing an innovative **cyber-physical system** to monitor, evaluate and optimize water use in real time.



27 Partners



11 Countries



5 Case Studies

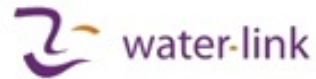


12.850.000€



51 months

# AquaSPICE Partners



# Motivation and Challenges



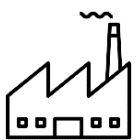
Climate change leads to **increasing water scarcity** problems



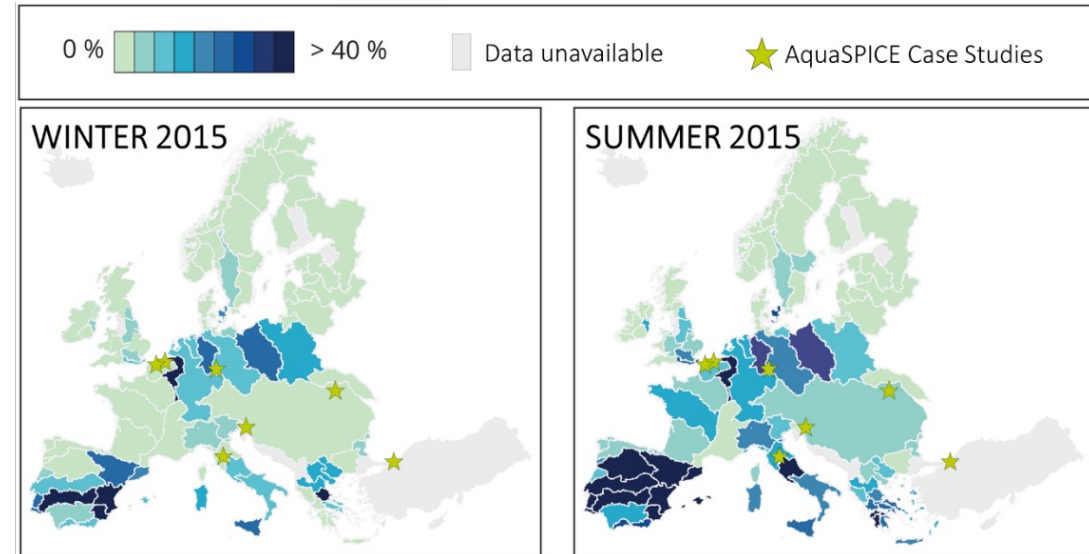
**Increasing global water use** at more than twice the population growth rate during the last century



**SDG 6:** Ensure the availability and sustainable management of water for everyone



**Industry relies on a sufficient water supply** in almost all production processes.  
**20%** of fresh water consumption & up to **50%** in **industrialized** countries



Water Exploitation Index by River Basin in 2015, adapted from:  
*“European Environment Agency, “The European environment: State and outlook 2020: knowledge for transition to a sustainable Europe,” Luxembourg, 2019.”*

# Impact on Water Resources in Relation to the Revised Industrial Emissions Directive (IED)

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## Water Use Efficiency

- **Reduction of Water Consumption**

The IED encourages industries to use water more efficiently, reducing water consumption. This is achieved through **process optimization, water recycling & reuse** within industrial operations.

- **Water Management Plans**

Industries must develop & implement water management plans that outline **strategies for reducing water usage & improving water quality**.

## Water Pollution Control

- **Emission Limits**

Strict limits on pollutants that can be discharged into water bodies, including heavy metals, organic pollutants, nutrients (nitrogen & phosphorus), and hazardous substances.

- **Monitoring and Reporting**

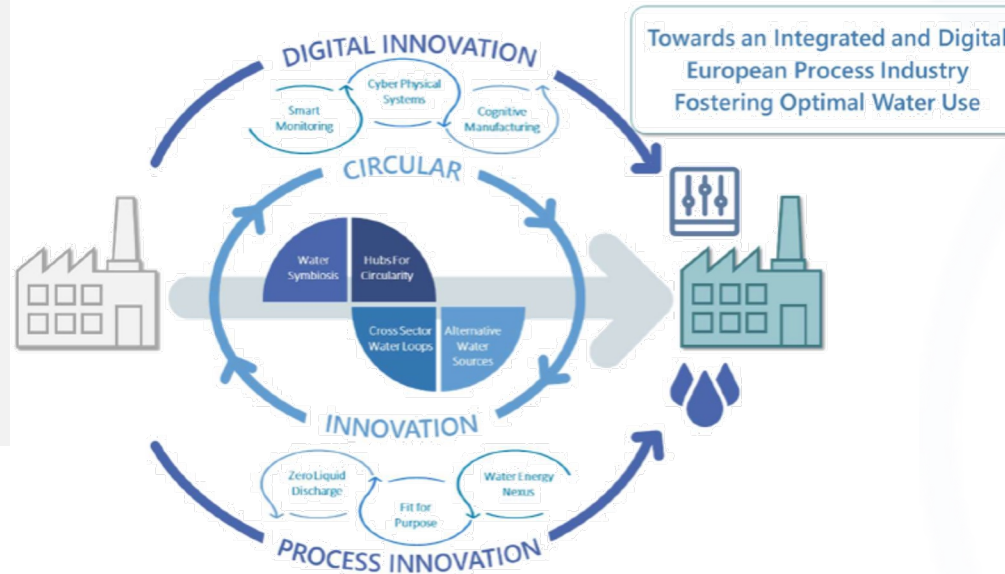
Industries are required to **monitor their emissions & report them regularly** to ensure compliance and continuous assessment of water quality.

# AquaSPICE Innovation Pillars

## Circular Innovation Pillar



- Water **re-use** at different levels
- Design, Monitoring and Evaluation of demonstration schemes using systemic **methodologies & tools**, based on holistic modelling concepts



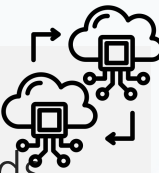
## Process Innovation Pillar



- Installation
- Operation
- Assessment of **advanced water treatment technologies & practices** with energy and substances recovery

## Digital Innovation Pillar

- Real-time monitoring** and distributed **data management system** connects the physical and digital worlds through smart sensor networks, IIoT and cloud/edge technologies
- Water-specific **Cyber-Physical-System (WaterCPS)** synthesises digital twins of industrial & value chain entities to provide advanced water-saving awareness & optimised water efficiency at different levels



# AquaSPICE Pilots

5 Industrial Case Studies – 7 Pilots



**DOW**

Technology focus for freshwater intake reduction at DOW

📍 Böhlen (DE), Terneuzen (NL)



Water treatment & re-use within peroxide production units, SOLVAY

📍 Tuscany and Marche (IT)



**BASF**  
The Chemical Company

Robust water treatment & re-use for the industrial zone of Antwerp, BASF

📍 Antwerp (BE)



  
water-link

Sustainable water management in Antwerp harbor and Albert canal

📍 Port of Antwerp (BE)



 **AGRICOLA**  
neam de gospodari

Sustainable water use in meat production at AGRICOLA

📍 Bacau (RO)



**Tüpraş**

Water treatment and re-use within refinery at TUPRAS

📍 Izmit (TU)

# AquaSPICE's systemic approach in water management

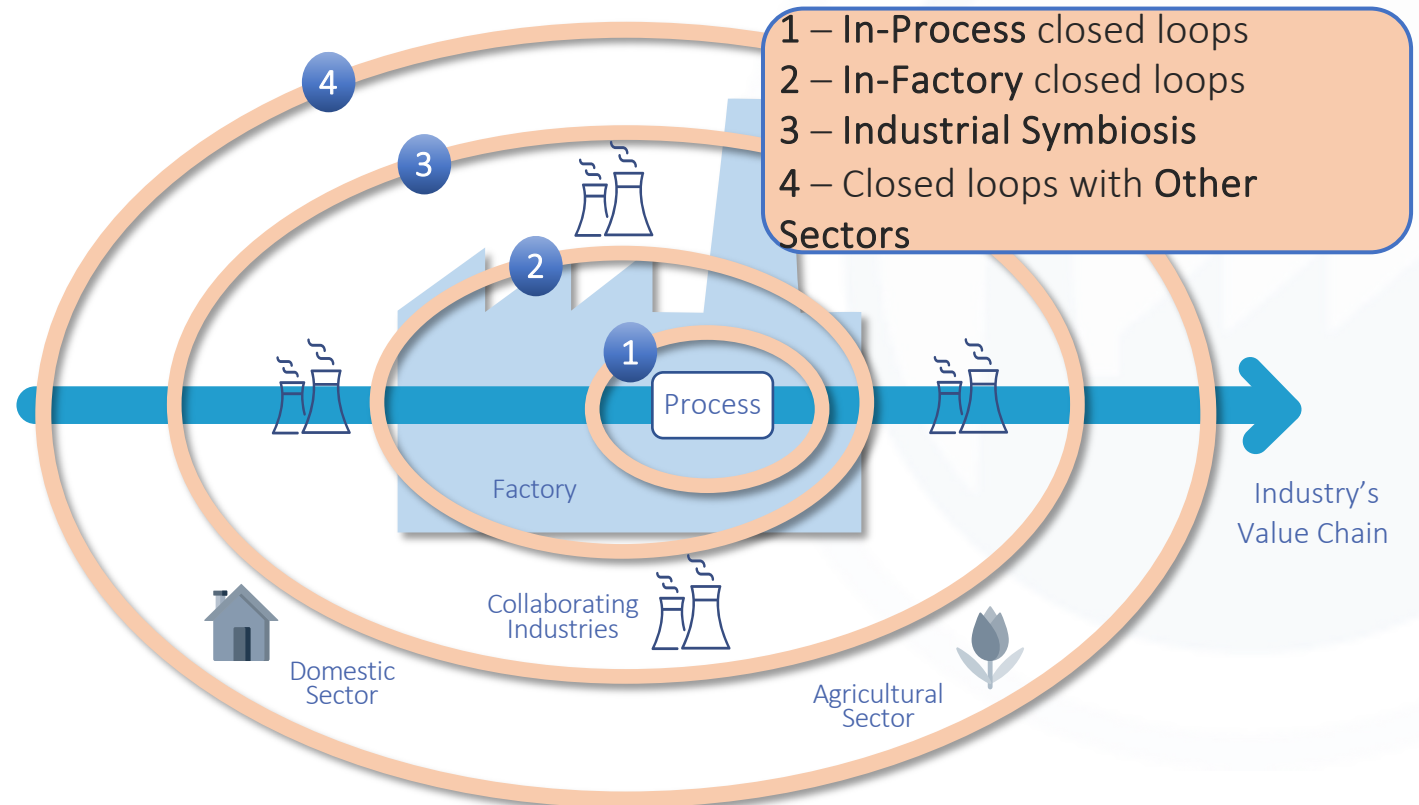
## Industrial Water Circular Practices

### Water policy relevance of AquaSPICE in the Circular Economy



- Fit-for-purpose technologies and practices
- Closed loops of water, substances and energy
- Establishment of synergies with same or other sectors

- **1 – In-Process closed loops**
  - DOW Böhlen, Terneuzen
  - TUPRAS, Turkey
- **2 – In-Factory closed loops**
  - BASF, Port of Antwerp
- **3 – Industrial Symbiosis**
  - AGRICOLA, Romania
- **4 – Closed loops with Other Sectors**
  - SOLVAY, ARETUSA, Italy





# Process Innovations

## Industrial Water and Wastewater Practices



### DOW

**Cooling Tower Blow Down treatment** with GAC/UF/RO to be reused as Make-Up Water in the cooling towers

**Condensate treatment** to be re-incorporated in the production chain

### Solvay, Aretusa

WAPEREUSE pilot plant to treat industrial **wastewater from peroxide production plant** by GAC/MBR/IEX/adsorption processes & reuse it for cooling & other purposes



# Process Innovations

## Industrial Water and Wastewater Practices



### Tüpraş

**Wastewater treatment** by biological reactor-UF-RO from oil refinery plant to be reused as firefighting & cooling water

### BASF

Treatment of **RO concentrate** or **other wastewater** by IEX & RO to be reused as BFW or regeneration agent



### Agricola

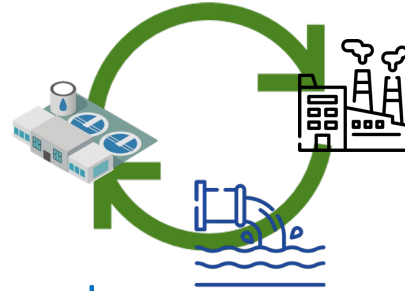
Treatment of **slaughterhouse wastewater** by MBR & UV to be reused within the plant

# Circular Innovations

## Industrial Water Circular Practices

### Solvay, Aretusa

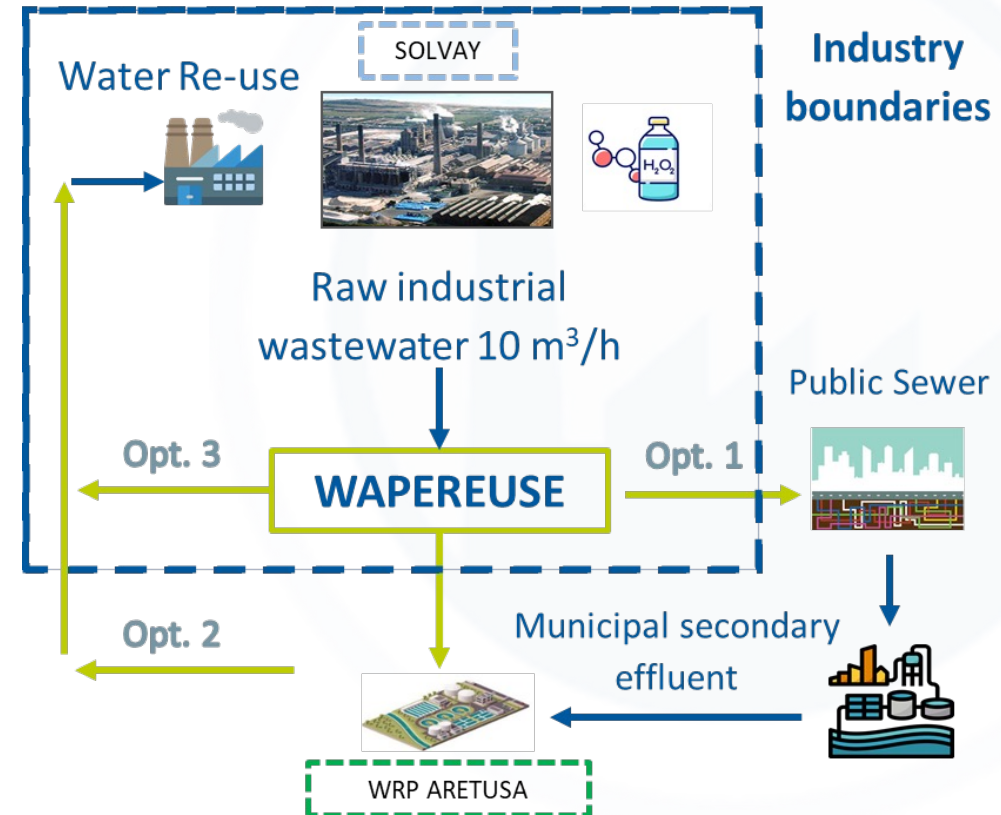
- Industrial wastewater treatment from the peroxide and peracetic acid production with advanced technologies
- Exchange of wastewater & water with other sectors (municipality with Rosignano WWTP and WRP Aretusa)
- Goal: Water reuse in the plant & Less wastewater production



Opt. 1: Treated industrial wastewater is discharged to public sewer at Rosignano WWTP & then to WRP Aretusa before its reuse at Solvay plant.

Opt. 2: Treated industrial wastewater is sent to WRP Aretusa to be further treated before its reuse at Solvay plant.

Opt. 3: Treated industrial wastewater is reused directly at Solvay plant for cooling purposes.



# Digital Innovations

## Water Cyber-Physical System (WaterCPS) development

- Cyber-Physical System (CPS) to **enhance water efficiency** in the **Process Industry**
  - **Digital twins** of industrial and value chain entities
  - **Tools for dynamic process** monitoring, analysis, simulation, adaptation, optimization and assessment
- Water efficiency enhancement is approached from 3 directions:
  - **Production chain enhancement** (design & implement water treatment and recovery technologies)
  - **Diagnostic** (monitor water efficiency, diagnose problems, estimate improvement margins)
  - **Optimization** (water use/recovery/reuse processes & practices)

## Water-Link, Antwerp harbor &



**Action:** CTD sensors network at > 40 locations

**Goal:** Predict water availability & quality in Antwerp port



**Digital monitoring of water treatment facilities**

# AquaSPICE WaterCPS

WaterCPS specialized to **enhance water efficiency** in the **Process Industry**

PHYSICAL

Existing Production Line – Product Value Chain

Water Saving – Treatment – Recycle – Reuse Practices/Technologies



sensors



Real-Time Monitoring Platform

Intelligent WaterCPS Services

Modelling & Simulation

Data Analytics

Optimization

Dynamic LCA

WaterCPS Digital Platform

Machine-Machine Interfaces

Digital Twins

Human-Machine Interfaces

Integrated Platform

DOW Terneuzen

DOW Böhlen

Solvay, ARETUSA

WATER-LINK

BASF

AGRICOLA

TUPRAS

CYBER  
(DIGITAL)

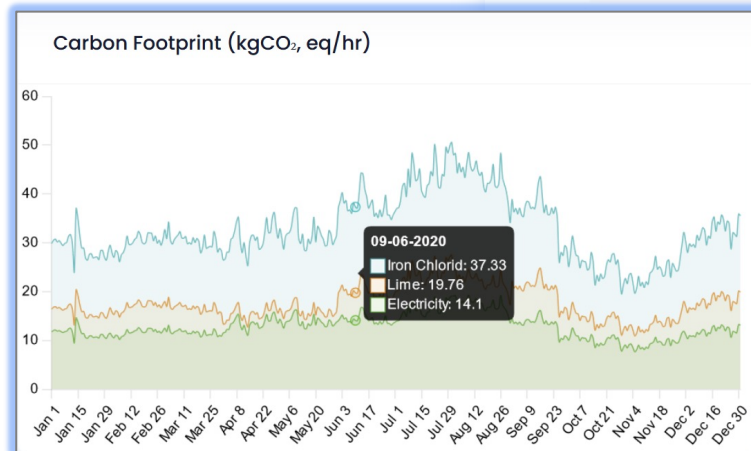
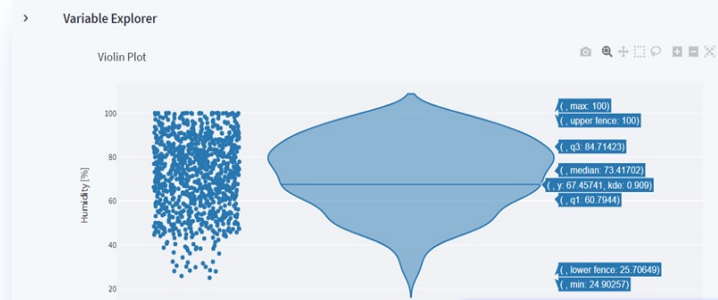
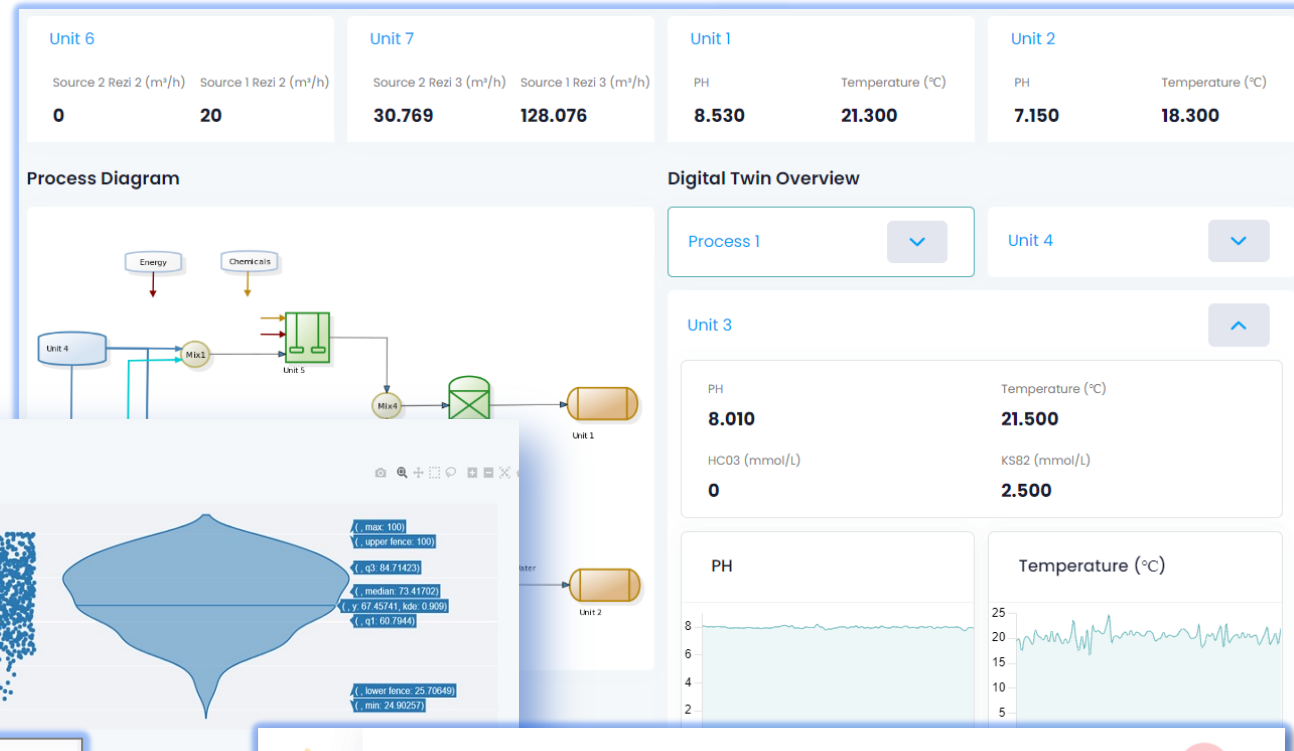
Application to  
Industrial Sites

# AquaSPICE WaterCPS

## Digital Twin based WaterCPS Platform

■ The Digital Twin of the industrial process can provide information about:

- Water Quantity and Quality
- Storage Quantities
- Warnings, Alerts and Failures
- Simulation Results
- Data Analytics
- Dynamic LCA
- Optimization Results



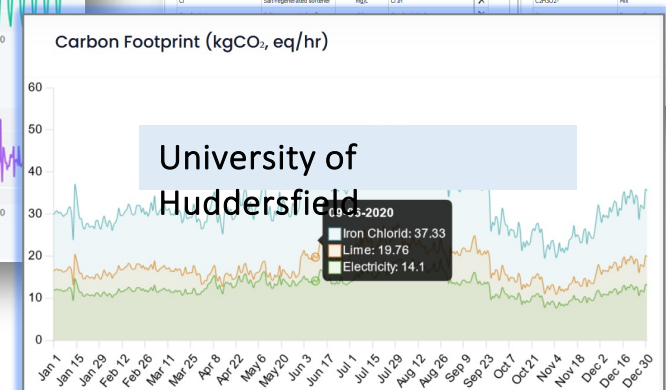
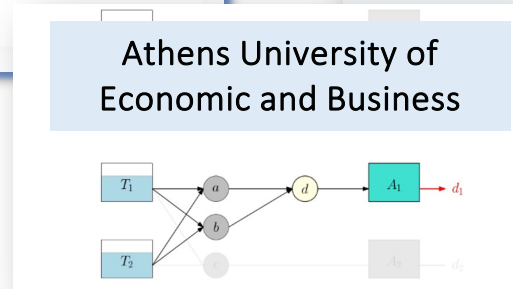
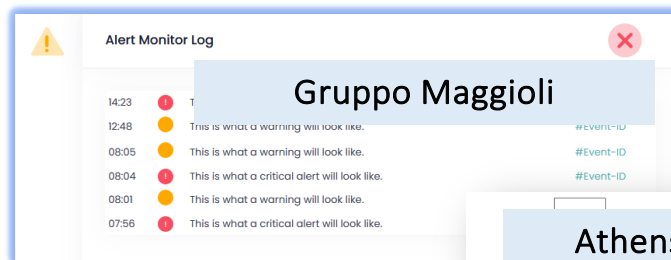
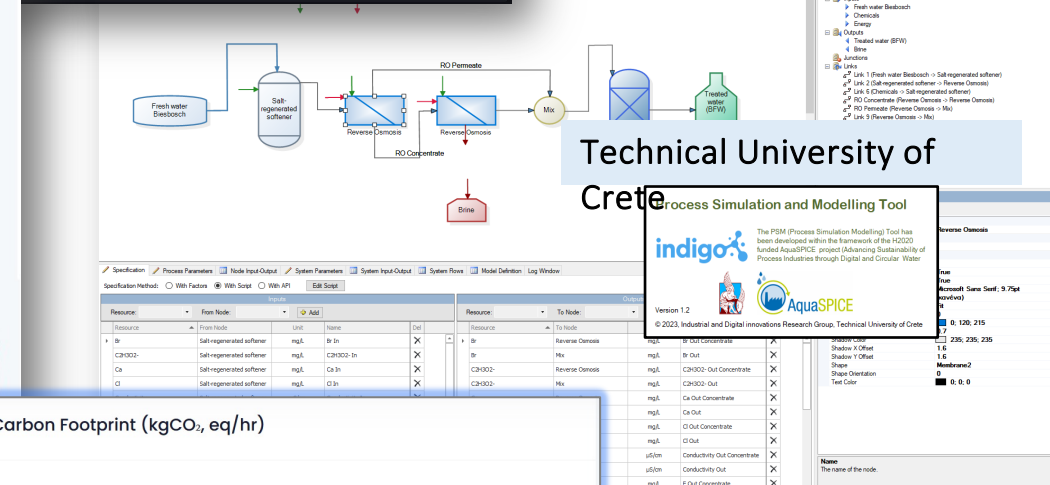
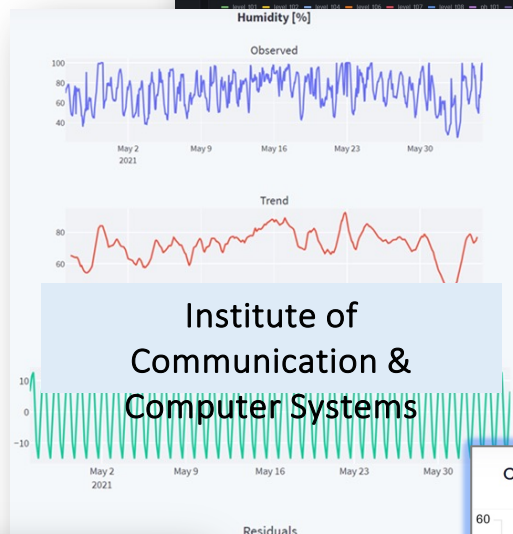
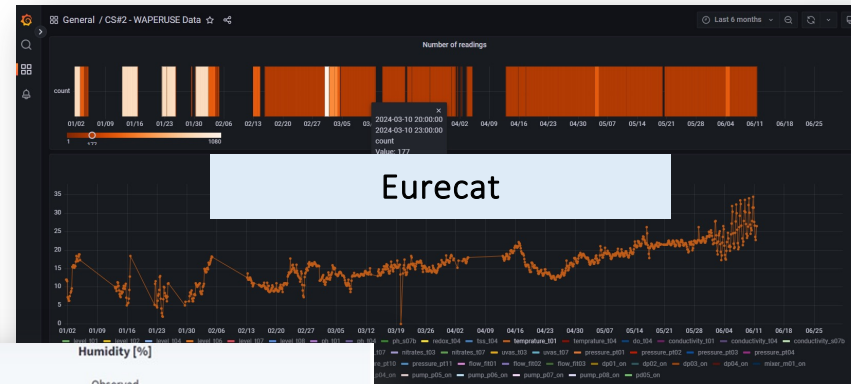
Timestamp	Alert Type	Description	Event ID
14:23	Critical	This is what a critical alert will look like.	#Event-ID
12:48	Warning	This is what a warning will look like.	#Event-ID
08:05	Warning	This is what a warning will look like.	#Event-ID
08:04	Critical	This is what a critical alert will look like.	#Event-ID
08:01	Warning	This is what a warning will look like.	#Event-ID
07:56	Critical	This is what a critical alert will look like.	#Event-ID

# AquaSPICE WaterCPS Services

## Digital Twin based WaterCPS Platform Services

■ Digital Twins of the industrial value chain to provide information about:

- Real-time Monitoring
- Process Modelling & Simulation
- Data Analysis (descriptive, predictive, etc.)
- Optimization
- Life Cycle Assessment



# WaterCPS Digital Platform Demo

## Cooling Towers Monitoring



Dashboard

Cooling towers - Monitoring

DIGITAL TWINS

Plants

Antwerp plant

Processes

Stream Cracker Process Streams

Cooling towers

Reverse Osmosis Concentrate

Stations

Splitter

Cooling Tower A

Cooling Tower B

Cooling Tower C

Cooling Tower D

Cooling Tower E

Cooling Tower F

Collector

### Cooling Towers

Execution State  
**Monitoring**

Water Inflow  
**6279.946** kg/s  
17/10/2023, 10:54 AM

Water Temperature  
**302** K  
17/10/2023, 10:54 AM

Air Temperature  
**293**  
17/10/2023, 10:54 AM

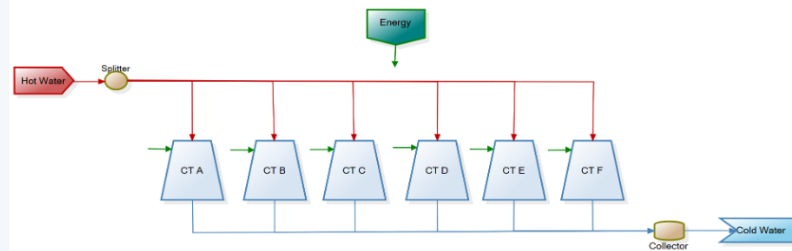
Humidity Ratio  
**0.012**  
17/10/2023, 10:54 AM

Towers On  
**5**  
17/10/2023, 10:54 AM

Fans On  
**5**  
17/10/2023, 10:54 AM

Total Energy  
**548.500** kW  
17/10/2023, 10:54 AM

### Cooling Towers Process Diagram



### Splitter

Water  
**6279.900** kg/s  
17/10/2023, 10:54

Temperature  
**302** K  
17/10/2023, 10:54

### Collector

Water  
**6231.400** kg/s  
17/10/2023, 10:54

Temperature  
**297.600** K  
17/10/2023, 10:54

### Cooling Tower A

Water  
**1246.300** kg/s  
17/10/2023, 10:54

Temperature  
**297.600** K  
17/10/2023, 10:54

### Cooling Tower B

Water  
**1246.300** kg/s  
17/10/2023, 10:54

Temperature  
**297.600** K  
17/10/2023, 10:54

### Cooling Tower C

Water  
**1246.300** kg/s

Temperature  
**297.600** K

### Cooling Tower D

Water  
**1246.300** kg/s

Temperature  
**297.600** K



# WaterCPS Digital Platform Demo

## Cooling Towers Anomaly Detection



**Alerts**

Date	Status	Alert Type	Description	Value	Twin
16-09-2023, 6:33 PM	<span style="color: red;">!</span>	Warning	Low Temperature	300	#Splitter

**Cooling towers - Monitoring**

Cooling Towers  
Execution State  
**Monitoring**

Towers On  
**5**  
17/10/2023, 10:54 AM

**Cooling Towers Process**

Water      Temperature      Water      Temperature  
**6279.900** kg/s      **302** K      **6231.400** kg/s      **297.600** K  
17/10/2023, 10:54      17/10/2023, 10:54      17/10/2023, 10:54      17/10/2023, 10:54

Cooling Tower A      Cooling Tower B

Water      Temperature      Water      Temperature  
**1246.300** kg/s      **297.600** K      **1246.300** kg/s      **297.600** K  
17/10/2023, 10:54      17/10/2023, 10:54      17/10/2023, 10:54      17/10/2023, 10:54

Cooling Tower C      Cooling Tower D

Water      Temperature      Water      Temperature  
**1246.300** kg/s      **297.600** K      **1246.300** kg/s      **297.600** K  
17/10/2023, 10:54      17/10/2023, 10:54      17/10/2023, 10:54      17/10/2023, 10:54

# WaterCPS Digital Platform Demo

## Cooling Towers Route Cause Analysis



**AquaSPICE**

Dashboard

DIGITAL TWINS

- Plants
  - Antwerp plant
- Processes
  - Stream Cracker Process Streams
  - Cooling towers**
  - Reverse Osmosis Concentrate
- Stations
  - Biological Activated Carbon
  - Mixed Bed
  - Reverse Osmosis
  - Storage Tank
  - Ultrafiltration

### Cooling towers Analytics

- descriptive
- timeseries
- anomalies

**Filters**

Variables

Select a variable: Humidity

Dates

Select Start Date: 2021/04/26 | Select End Date: 2021/06/05

Reset

variable

- Humidity [%]
- Inlet air temp [C]
- Inlet liquid temp [C]
- Outlet/inlet liquid flow rate [M3/HR]
- Outlet liquid temp [C]
- blowdown [T/HR blowdown]
- Makeup water flow [M3/HR]
- B3201A Vermogen ventilator motor [kW]
- B3201A Toerental regelaar ventilator [AO%]
- B3201B Vermogen ventilator motor [kW]
- B3201B Toerental regelaar ventilator [AO%]
- B3201C Vermogen ventilator motor [kW]
- B3201C Toerental regelaar ventilator [AO%]
- B3201D Vermogen ventilator motor [kW]
- B3201D Toerental regelaar ventilator [AO%]

### Variable Explorer

Violin Plot

# WaterCPS Digital Platform Demo

## Cooling Towers Optimisation and Simulation



⏪

Dashboard

**Cooling Towers - Optimization**

DIGITAL TWINS

Plants

● Antwerp plant

Processes

Stream Cracker Process Streams

● Cooling towers

Reverse Osmosis Concentrate

Stations

Splitter

Cooling Tower A

Cooling Tower B

Cooling Tower C

Cooling Tower D

Cooling Tower E

Cooling Tower F

Collector

Cooling Towers

**Execution State**  
**Simulation**

Water Inflow  
**6279.946** kg/s  
21/9/2023, 10:07 AM

**Water Temperature**  
**300** K  
21/9/2023, 1:39 PM  
**Total Energy**  
**329.100** kW  
21/9/2023, 1:39 PM

Air Temperature  
**293**  
21/9/2023, 10:07 AM

Humidity Ratio  
**0.012**  
21/9/2023, 10:07 AM

Towers On  
**3**  
21/9/2023, 1:39 PM

Fans On  
**3**  
21/9/2023, 1:39 PM

Cooling Towers Process Diagram

Splitter

Water  
**2073.500** kg/s  
21/9/2023, 1:39 PM

Temperature  
**297.700** K  
21/9/2023, 1:39 PM

Collector

Water  
**6231.400** kg/s  
21/9/2023, 1:39 PM

Temperature  
**297.700** K  
21/9/2023, 1:39 PM

Cooling Tower A

Water  
**2073.500** kg/s  
21/9/2023, 1:39 PM

Temperature  
**297.700** K  
21/9/2023, 1:39 PM

Cooling Tower B

Water  
**2073.500** kg/s  
21/9/2023, 1:39 PM

Temperature  
**297.700** K  
21/9/2023, 1:39 PM

Cooling Tower C

Water  
**0** kg/s

Temperature  
**0** K

Cooling Tower D

Water  
**0** kg/s

Temperature  
**0** K

# Thank you for your attention

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Technical University of Crete (TUC), Greece



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