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2 July 2024

University of Crete, Greece

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intelligent Water Treatment Technologies for water preservation combined with simultaneous energy production and material recovery in energy intensive industries

intelWATT

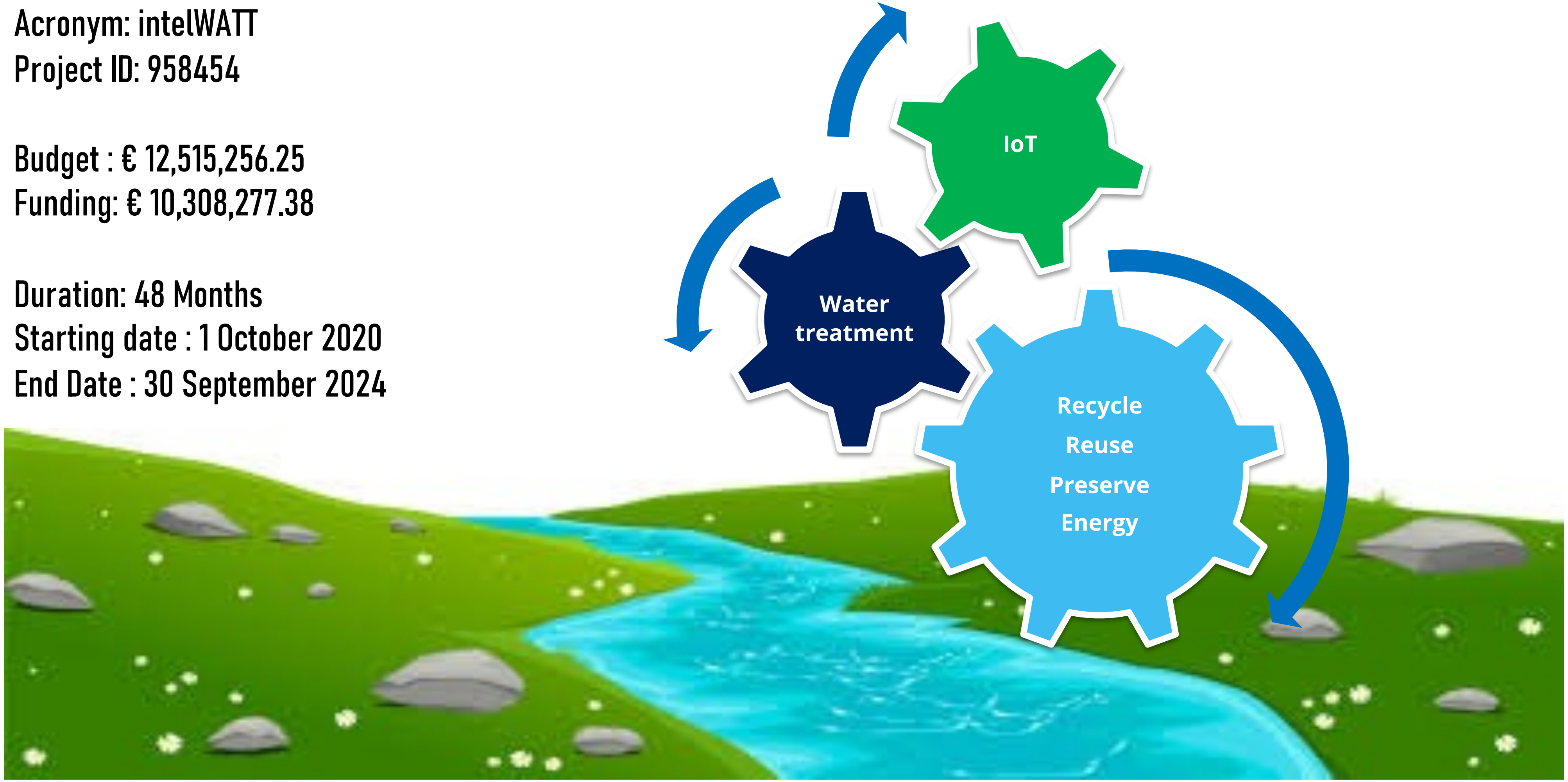
“This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 958454”.

intelligent Water Treatment Technologies for water preservation combined with simultaneous energy production and material recovery in energy intensive industries

Acronym: intelWATT
Project ID: 958454

Budget : € 12,515,256.25
Funding: € 10,308,277.38

Duration: 48 Months
Starting date : 1 October 2020
End Date : 30 September 2024



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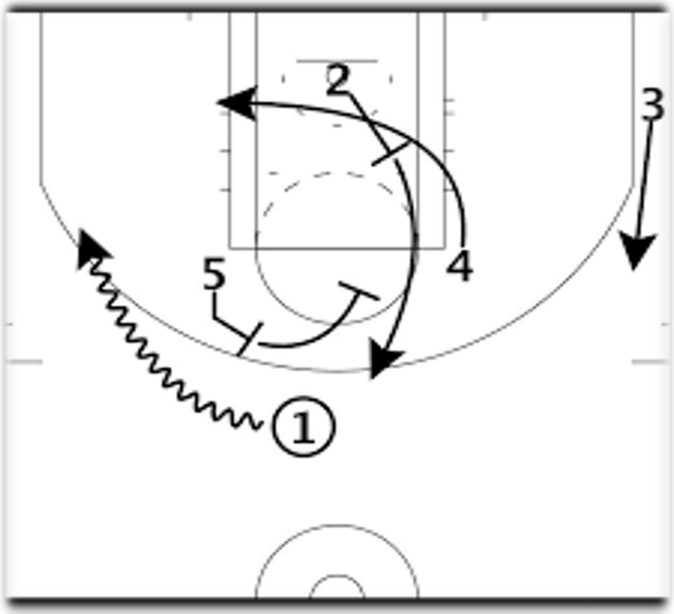
Concept



The general concept of the project is to effectively **integrate wastewater treatment processes with intelligent and decision making mechanisms** and to demonstrate these solutions in a series of case studies in industrial environment.

The proposed processes will be able **to adapt and adjust** the treatment conditions in **real time** according to wastewater inlet composition and the desired water product requirements.

These will be accomplished by a series of tailor made sensors which will feed their data to decision making software, over a middleware agnostic platform which in term will **calculate and adjust process conditions** such as: pretreatment method(s), operating pressure and temperature, flow and reflux rates, etc., in order to minimize the energy consumption while intensifying the volume production of reusable water.

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Main objective

The main objective of the intelWATT proposal is to validate, at TRL7-8, innovative & intelligent water treatment technologies combining fresh water preservation with resources recovery and energy conversion based on the circular economy concept. This will be demonstrated through three different case studies in representative energy intensive industrial activities (power generation, mining, manufacturing-electroplating):

a) fresh water preservation through a >99% reduction of cooling tower blow down (CTBD) in a combined cycle natural gas power plant,

b) energy conversion and water recovery from a symbiotic scheme exploiting mining and wastewater effluents and

c) a closed loop for the simultaneous recovery of valuable metals and wastewater treatment to significantly reduce heavy loaded wastewater effluents & process costs in a plastic electroplating facility.

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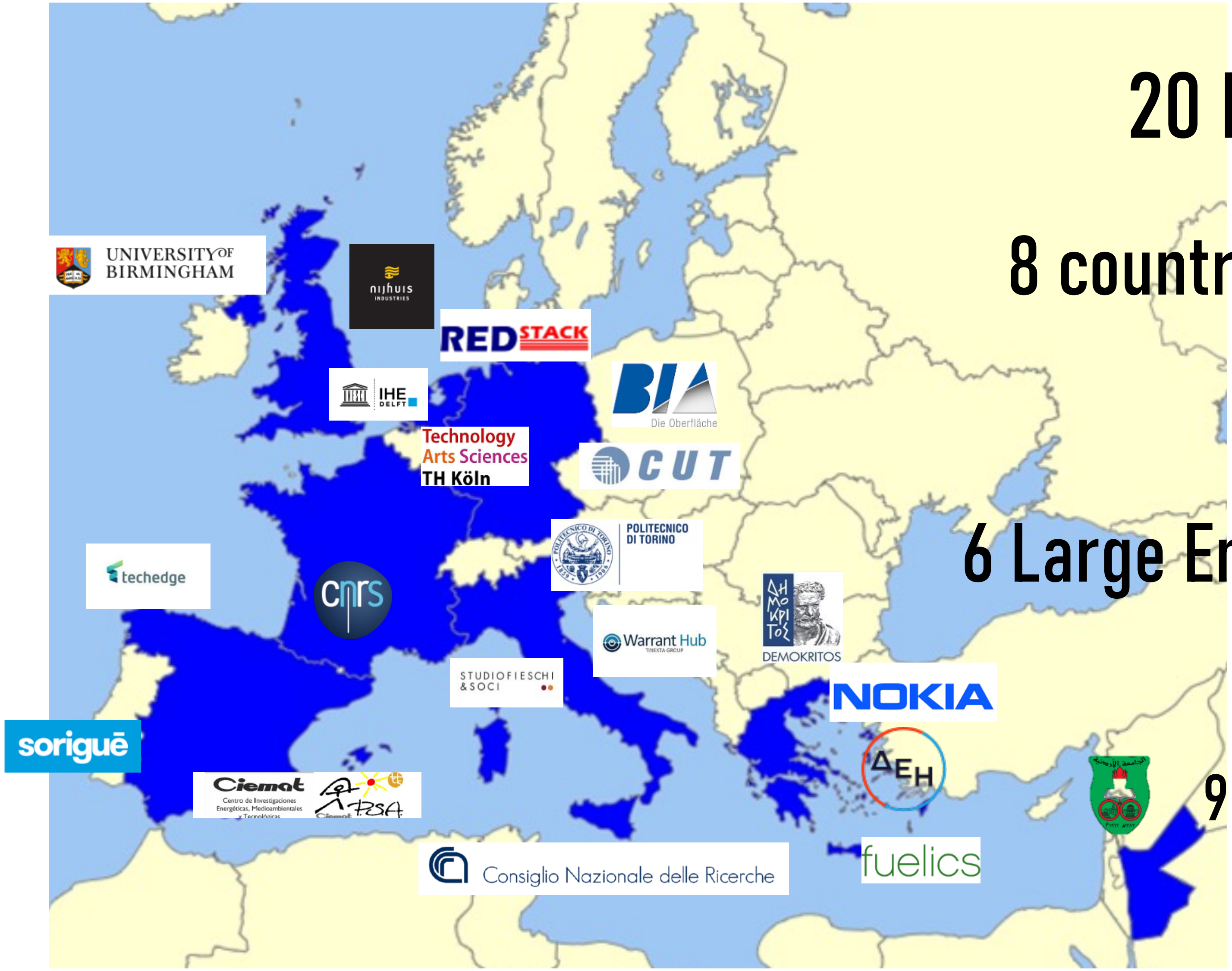
intelWATT

Consortium



20 Partners

8 countries

5 SMEs

6 Large Enterprises

9 Academic Institutions

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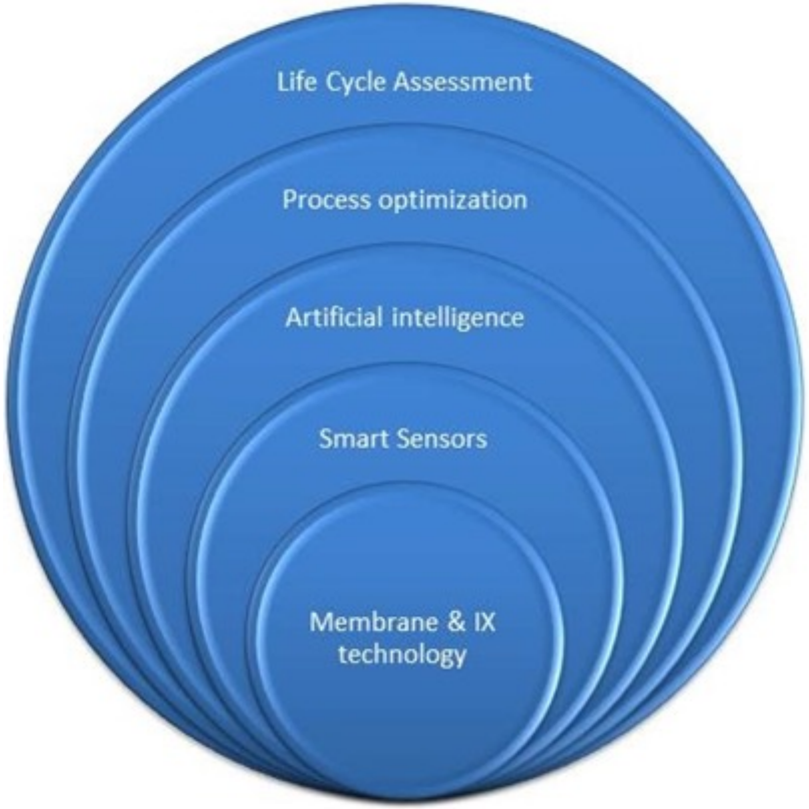
Project pillars



The project methodology is structured **in three main phases**

Detailed characterization of the three selected case studies water streams; determination of water quality key parameters and specifications of critical unit components (such as ion exchange capacity, membrane selectivity and flow rates etc.) and smart sensor requirements

Implementation of **tailor-made smart sensors** with edge computing capability for online monitoring of the pre-defined parameters, in conjunction with **deep machine learning control methods**.

Customization of membrane and resin-based elements with targeted properties. Water treatment process optimization, at lab scale under realistic conditions

Evaluation in industrial environment of the new technologies' performance, reaching the main milestones of water preservation, substances' recovery and energy generation

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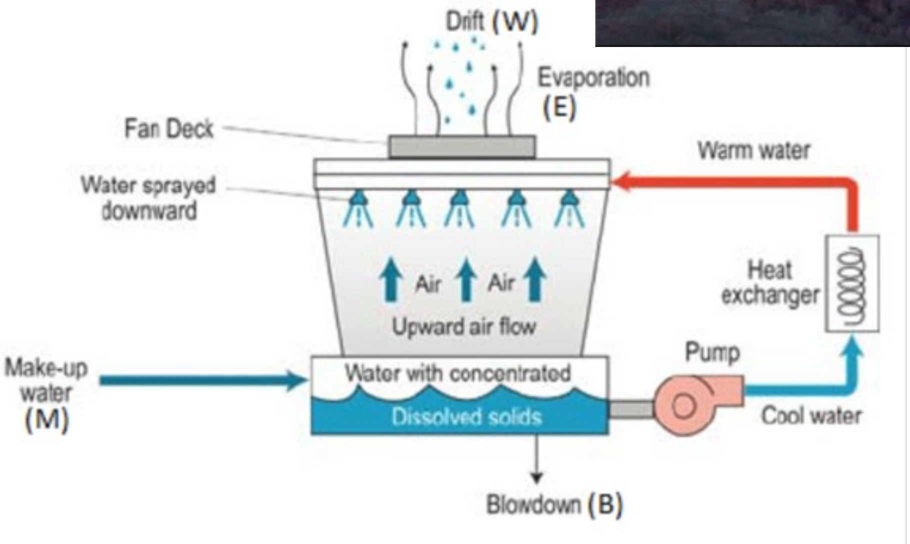
Case study 1

Fresh water preservation in combined cycle power plant

OBJECTIVE

Demonstration prototype for CTBD treatment. The development of efficient, cost effective, smart solutions for water management in a thermoelectric power plant, aiming at **minimization of the cooling tower blow down (>99% recovery) through developing a pilot unit of 100 m³/d** treatment capacity installed at the premises of PPC's unit V (800 MW natural gas combined circle facility, Megalopolis, Greece) based **on a closed-loop, near zero liquid discharge** approach.



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Case study 1

Fresh water preservation in combined cycle power plant

Problem to solve

To fully recover a wastewater discharge of 150-170 m^3/h

Proposed solution

A combination of 3 membrane based technologies (Nanofiltration, Reverse Osmosis and Membrane distillation) valorizing the waste heat of the power plant, aiming towards Zero Liquid Discharge of minimum specific energy consumption

Impact

Cooling towers are an industrial standard having replication potential in a vast spectrum of applications. Water preservation potential 1.000.000 – 1.500.000 m^3/year equivalent to consumption of 35.000 people / year

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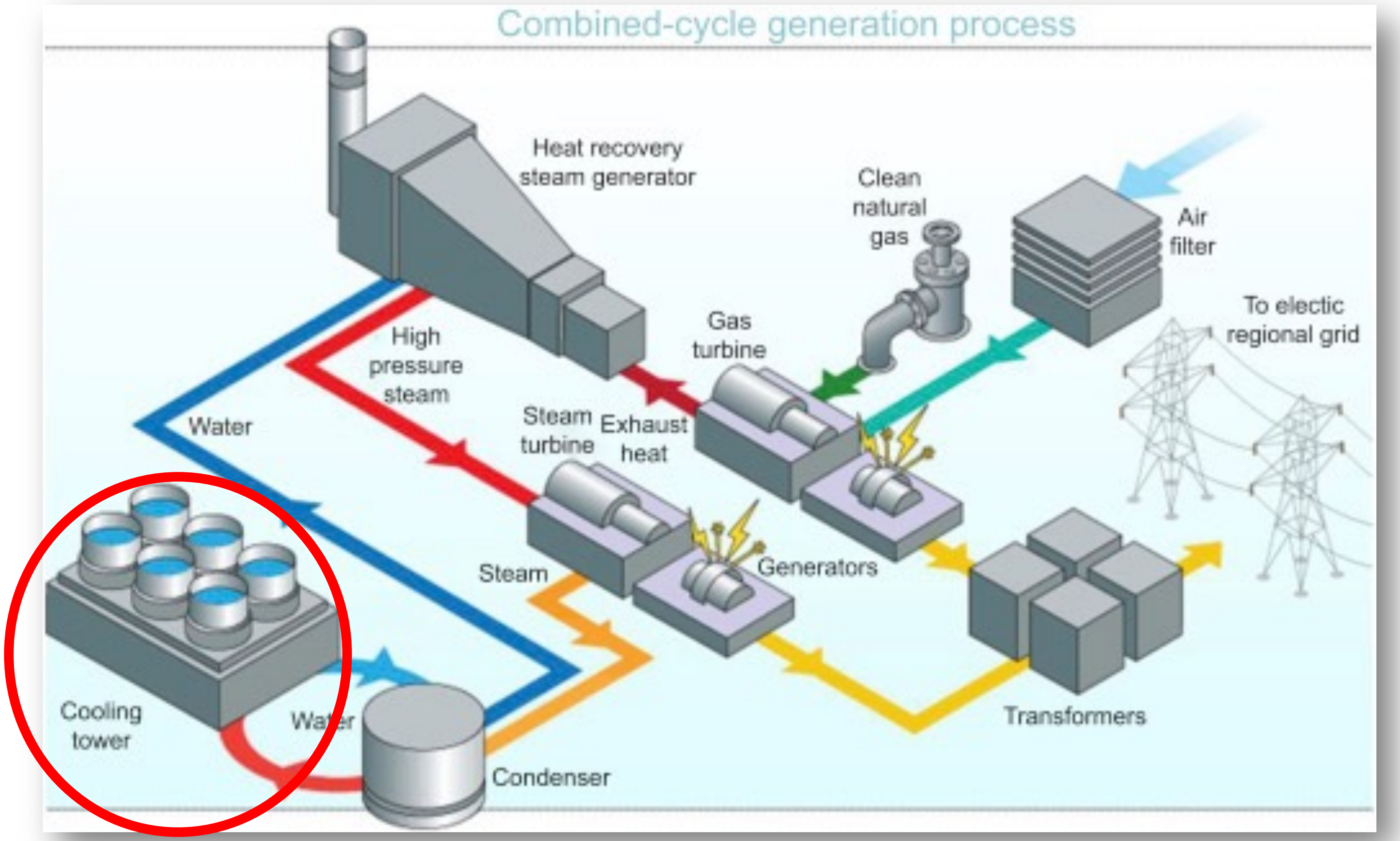

https://www.easterngeneration.com/rollinghillsproject.com/how.html

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Case study 1

Lab environment evaluation

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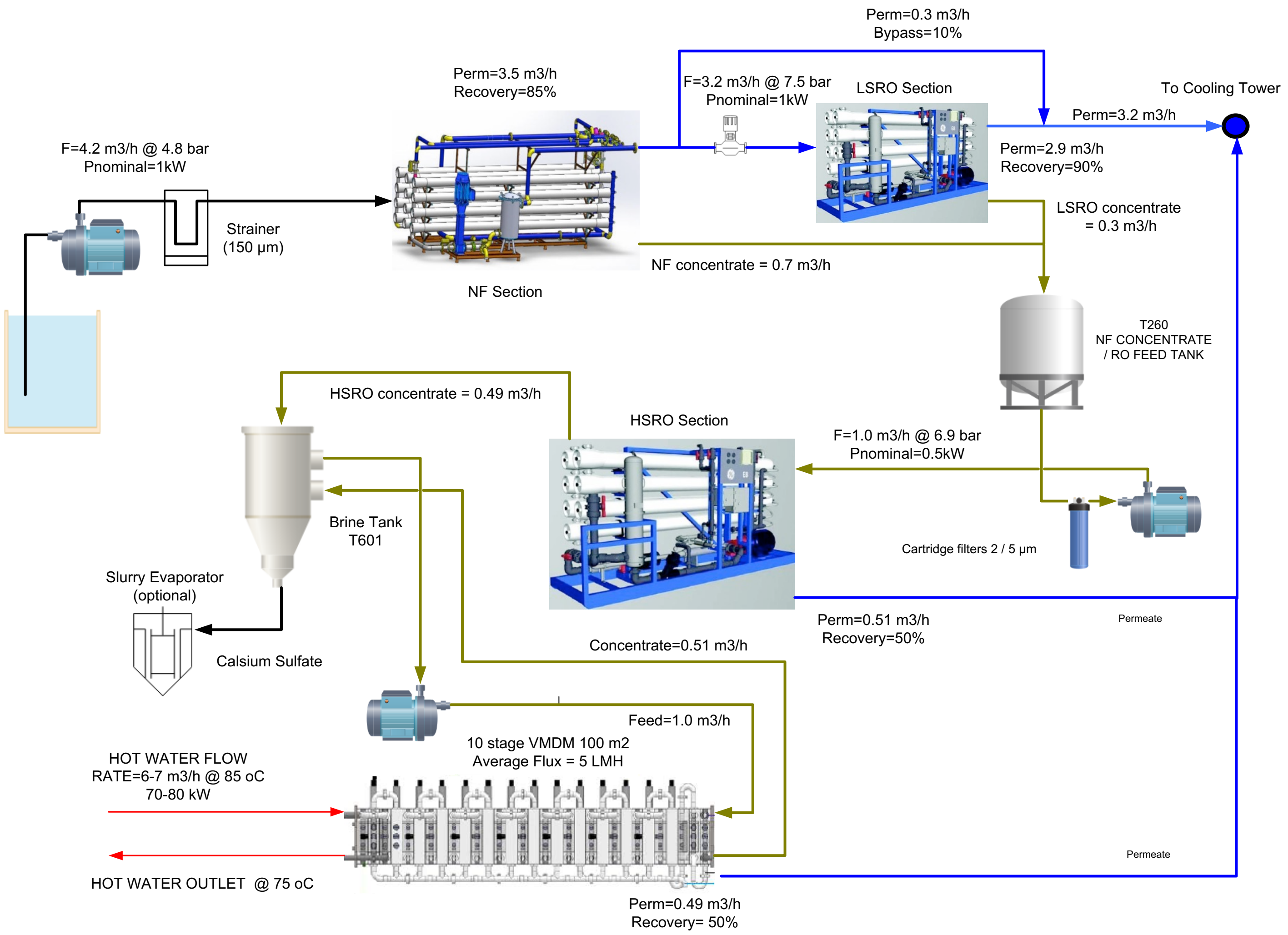
Task 3.1 Overview of CTBD Pilot Unit



- Two pressure driven membrane processes in series (Nanofiltration-NF and Reverse Osmosis-RO) for approximately 90% recovery of the CTBD water

- A temperature driven Membrane Distillation (MD) /Crystallisation (MCr) section developed by NCSRD, THK, CNR-ITM, CIEMAT & CUT for the achievement of the Zero Liquid Discharge target

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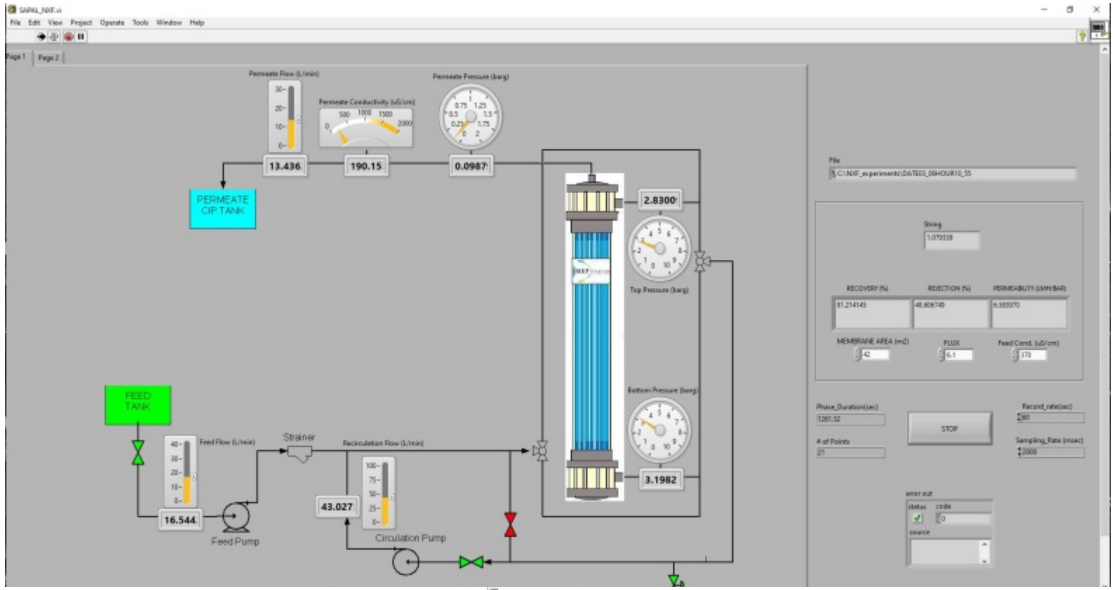
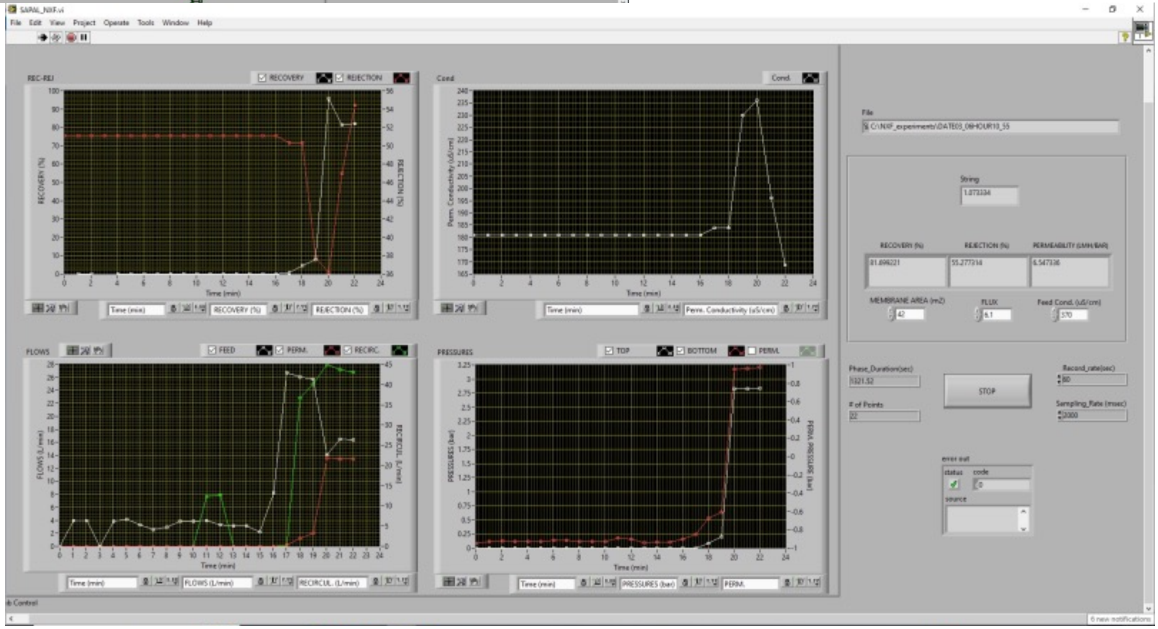
NF Lab Unit Setup





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Real-time monitoring

- The signals from the sensors are duplicated in real time by fitting a mirroring pass-through electronics module, called **SensorConn420**.
- Data is accessible on a cloud platform with the use of **Sensorveil**, a wireless network developed by **Fuelics** capable of non-intrusive data duplication of sensor or actuator signals. It includes an integrated remote management engine that is utilized to remotely control the network specifications.
- It utilizes **Zigbee** meshed technologies as a backbone wireless protocol that harvests data from the factory floor.
- Actuating parts of the industrial process are being duplicated using **ActutorConn** modules, equipped with a LCD screen, to monitor the measurements, while also being transmitted through a 850 MHz to the **AI Data Lake** to train a model that will eventually optimise the industrial process based on specific KPIs.
- So far, Fuelics has experimented with a **2.45 GHz gateway** that we initially deployed for proof before migrating to 850 MHz, a frequency capable of covering large areas of coverage.

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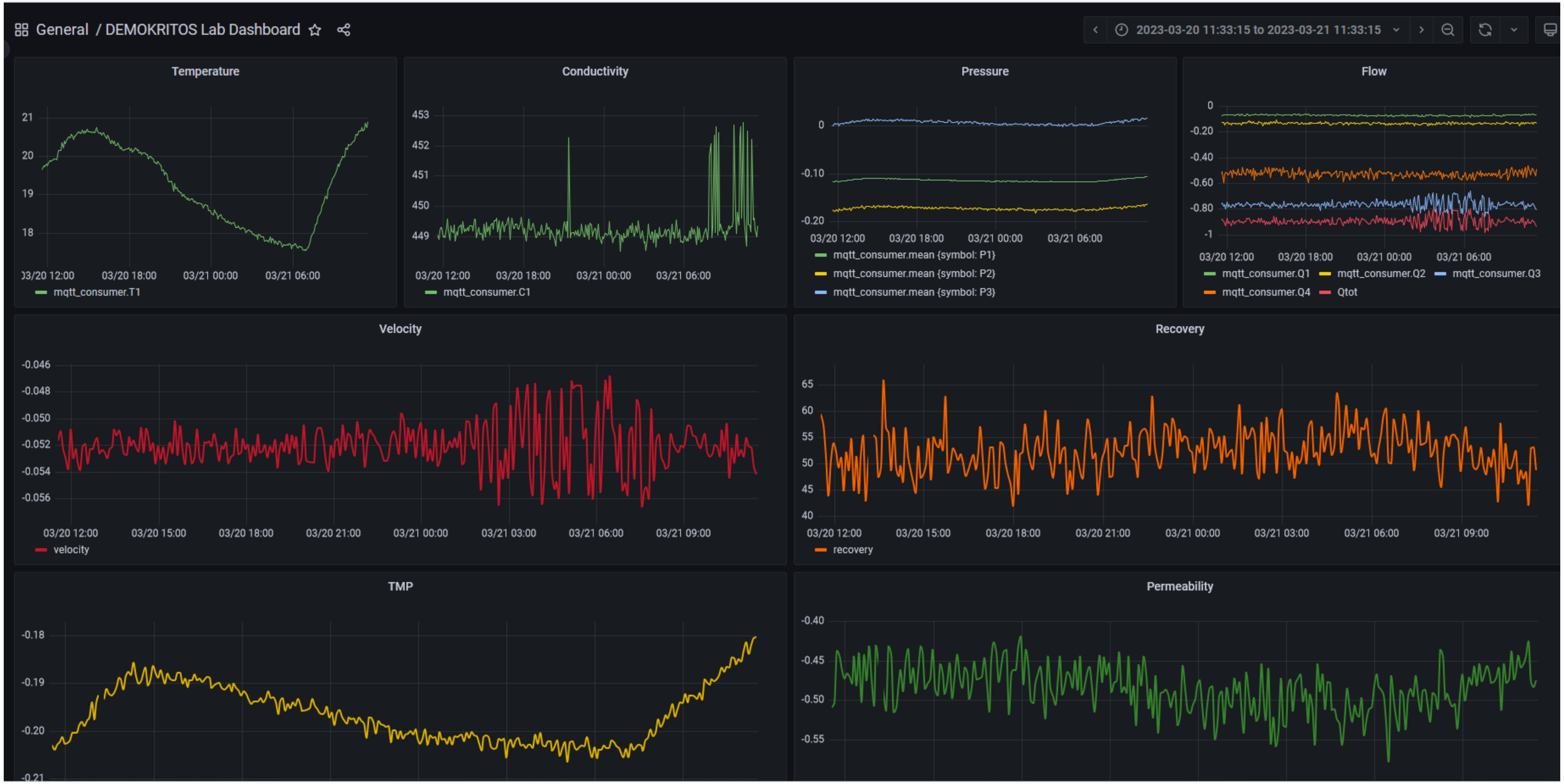
Real-time monitoring



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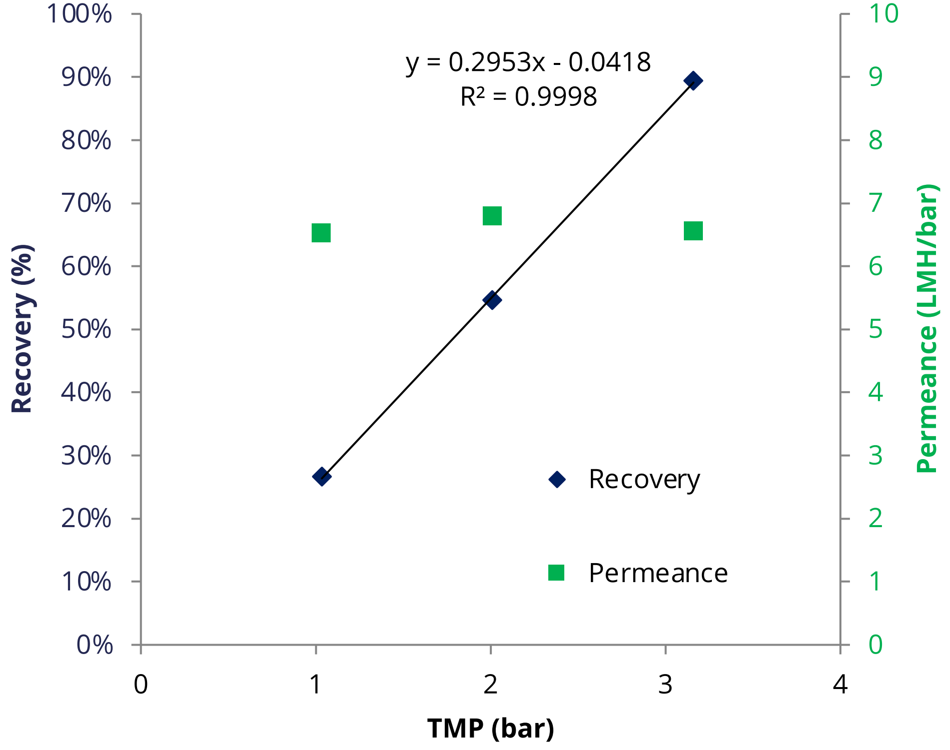
Results – CTBD

Main ion concentrations and water quality parameters for CTBD and make-up water

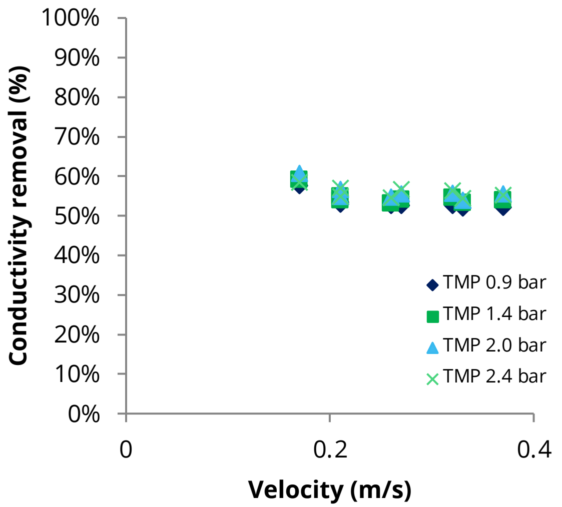
Parameters	Units	CTBD	Make-Up
pH		8.0	9.7*
Conductivity	μS/cm	840	315
TDS	mg/L	684	170
Total hardness	mg/L $CaCO_3$	274	110
K^+	mg/L	3.3	0.7
Na^+	mg/L	85.0	21.8
Ca^{2+}	mg/L	70.0	24.0
Mg^{2+}	mg/L	35.2	7.1
HCO_3^-	mg/L	97.6	12.2
Cl^-	mg/L	72.0	19.0
SO_4^{2-}	mg/L	372.0	80.0
PO_4^{3-}	mg/L	0.4	0.1

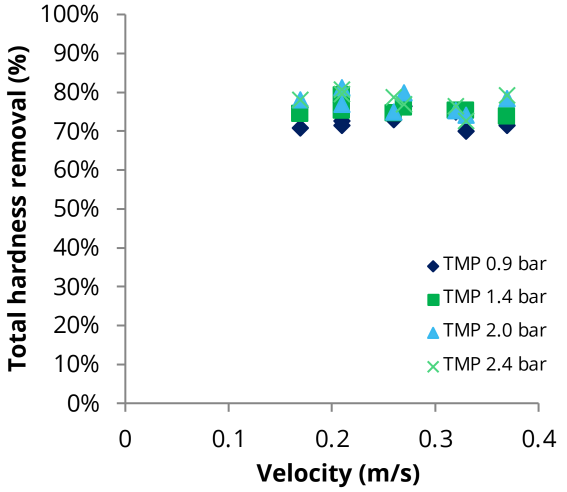


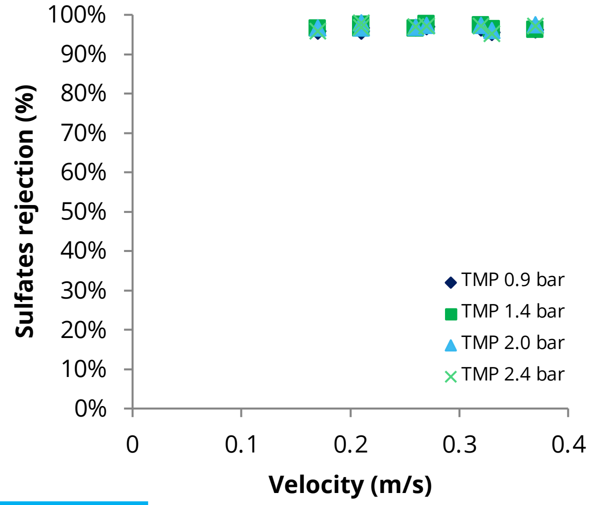
Total suspended solids < 1 ppm
Total Hardness < 110 ppm as $CaCO_3$
Turbidity < 1 Nephelometric unit
Total Carbonate hardness < 40 ppm $CaCO_3$
Chloride < 20 ppm

*Unpublished data.

Results – CTBD







Parameters	Units	CTBD Feed	Feed flow 1 m³/h			Feed flow 2 m³/h		
			Permeate	Concentrate	R%	Permeate	Concentrate	R%
pH		**8.1**	7.6	7.7		7.7	7.7	
Conductivity	μS/cm	**840**	403	964	52.0%	402	904	52.1%
Turbidity	NTU	**0.55**	0.12	1.13	78.2%	0.07	0.88	87.3%
Total Hardness	mg/L $CaCO_3$	**259**	78	336	69.9%	74	339	71.4%
Ca^{2+}	mg/L	**70.0**	21.4	84.8	69.4%	21.8	76.3	68.8%
Mg^{2+}	mg/L	**35.2**	8.6	43.3	75.6%	8.9	38.6	74.8%
K^+	mg/L	**3.3**	2.8	3.4	14.9%	2.8	3.4	15.2%
Na^+	mg/L	**85.0**	55.1	94.1	35.2%	54.0	89.0	36.5%
SO_4^{2-}	mg/L	**372**	16.6	483	95.5%	14.1	407	96.2%
Cl^-	mg/L	**76**	85.2	68.8	-12.1%	95.0	75.2	-25.0%

Physicochemical parameters for recirculation of 5 m³/h and TMP of 0.9 bar for feed flow of 1 and 2 m³/h.

- **Conductivity removal > 52%**
- **Total hardness removal > 70%**
- **Sulfates rejection > 95%**

*Unpublished data.

Case study 1

Fresh water preservation in combined cycle power plant

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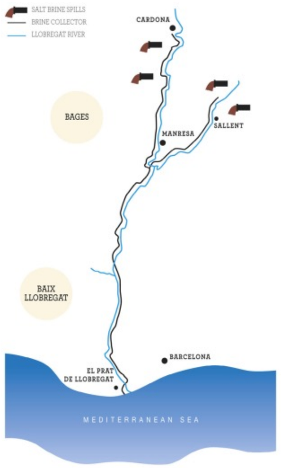
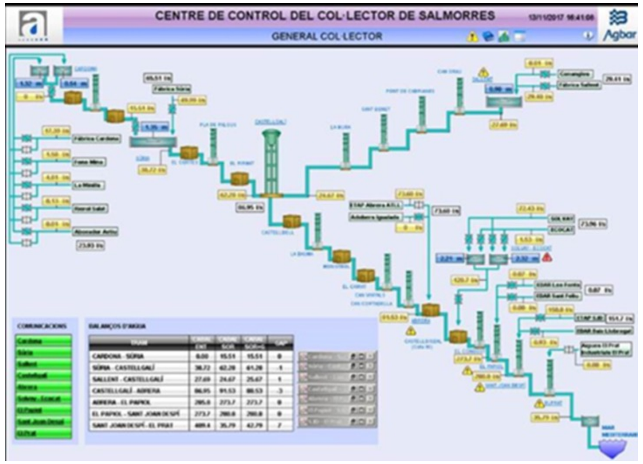
Case study 2

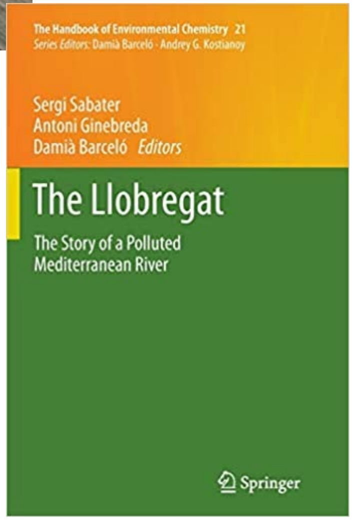
Hybrid process for water recovery and energy harvesting from industrial brines


El problema de la salinitat de les aigües de Barcelona

sorigué







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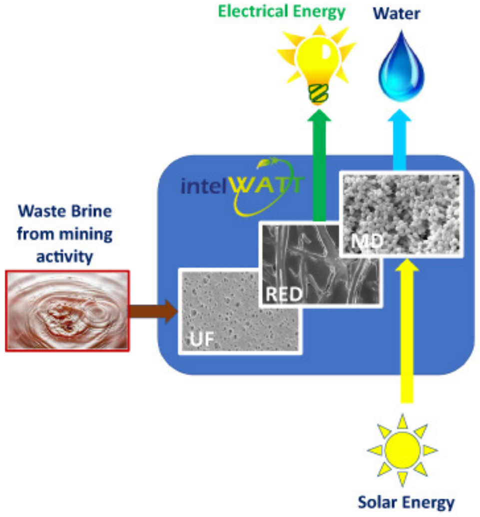
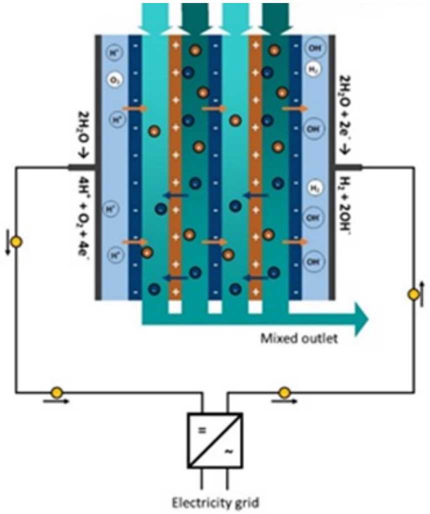
Case study 2

Hybrid process for water recovery and energy harvesting from industrial brines

OBJECTIVE
Demonstration of a symbiotic concept between industries: sustainable production of energy and water. In this context, an integrated pilot unit comprised by Reverse Electrodialysis (RED) and solar powered membrane distillation (MD) systems will be installed at the Castellgalí near Barcelona, Spain.
The low salinity source for the RED unit can be the effluent of one of the Drinking Water Treatment Plants (DTWP), discharging the effluent on the same brine collector. Though due to site location, technical and financial reasons, the pilot unit will be fed with brackish water from a nearby groundwater source as a proxy for the DTWP effluent. The combination o the brine and brackish ground water in the RED **will produce >3 MJ of electric energy per m^3 of brine**. The pilot will use a total feed of 100 m3/day, combined brine and brackish ground water feed flow rate, and ir the same time produce 25 m3/day of deionized water for different reuse purposes. The solar assisted water production along with the electric energy generated, which will be supplied to a neighborhood end user, ensures the sustainability of the proposed technological innovation.
This approach valorizes two "pollution sources" in order to produce energy and fresh water demonstrating at large scale conditions the **industry symbiosis concept.**





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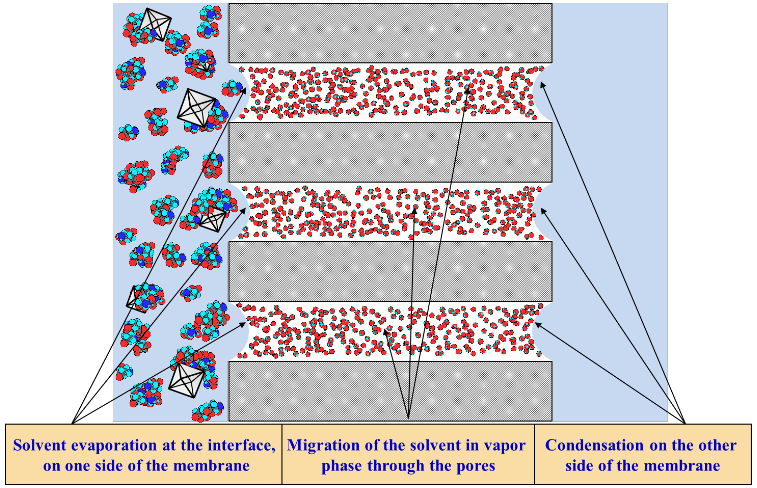
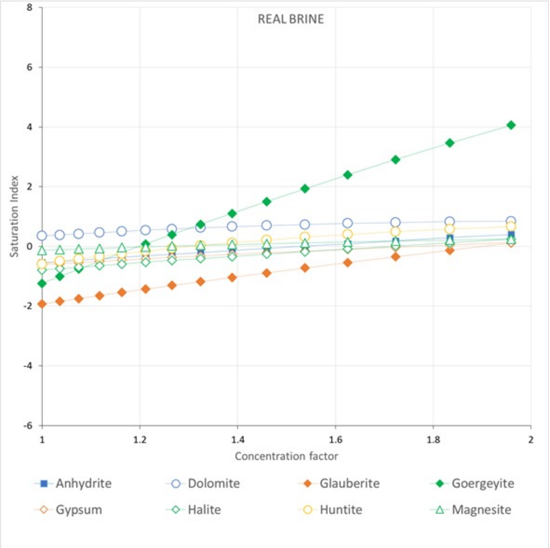
EXPERIMENTAL TESTS - MCr

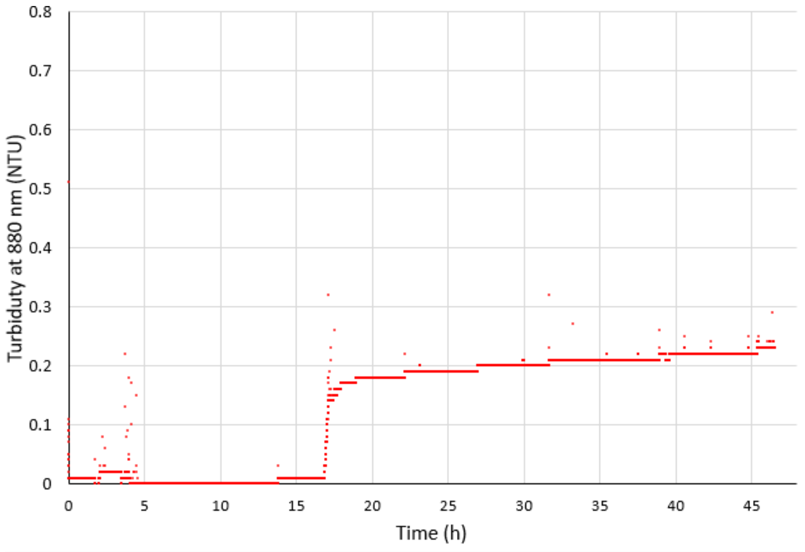
Evaluation of the possibility to recover valuable materials (e.g. magnesium salts) from the real brine



Specific Advantages of MCr process:*

- Fine control of the solution supersaturation by controlling permeation flux;
- Membrane heterogeneous nucleation;
- Continuous, modular and easy to scale-up and down.





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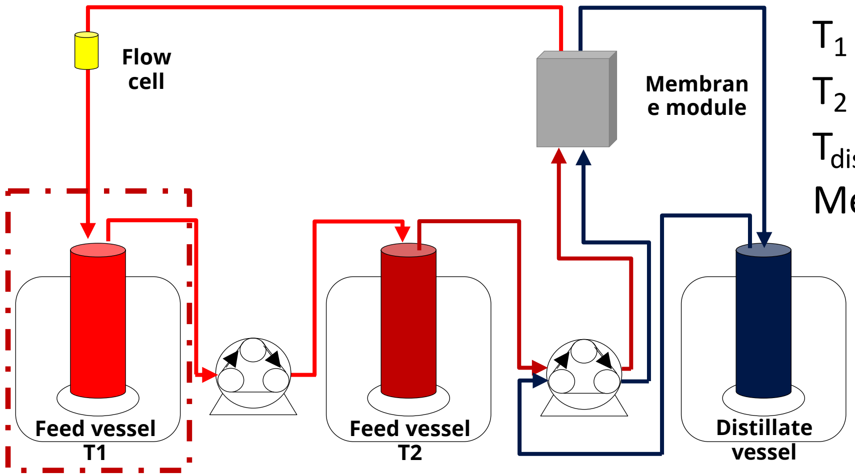
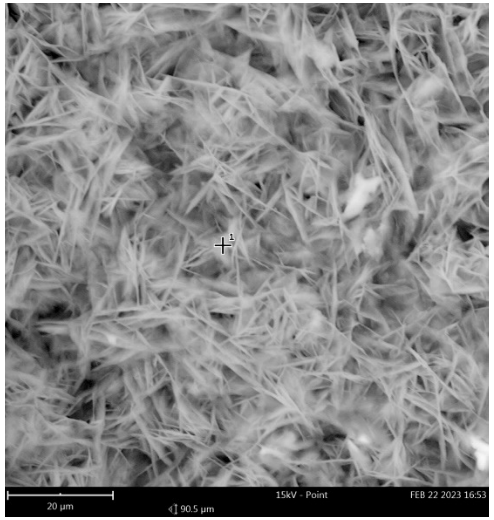
* E. Drioli, G. Di Profio, E. Curcio, Membrane-Assisted Crystallization Technology, Advances in Chemical and Process Engineering Series, World Scientific Publishing. November 2015

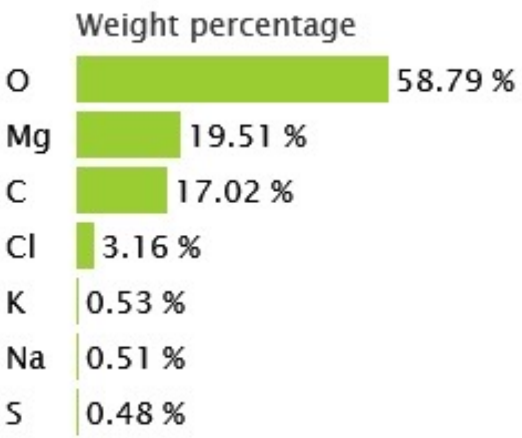
RESULTS - MCr

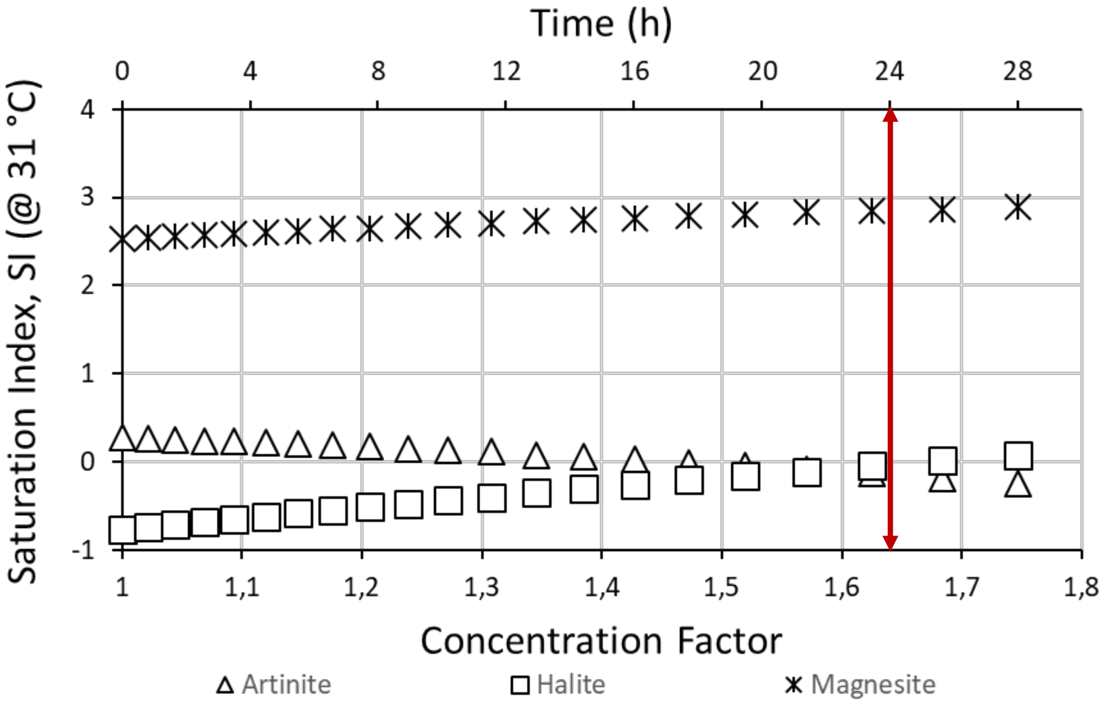
Sample 9: real brine, pretreated, T1 31 °C



T_1 31.1 °C
T_2 43.6 °C
T_{dist} 17.8 °C
Membrane area 24 cm^2







Sample ID	9
Concentration Factor	1.64
Specie	SI
	2.85
	-0.05
Barite - $BaSO_4$	-0.06
Artinite - $Mg_2CO_3(OH)_2 \cdot 3H_2O$	-0.13
Nesquehonite - $MgCO_3 \cdot 3H_2O$	-0.24
	-0.43
Nahcolite - $NaHCO_3$	-0.9

PXRD
Magnesite: 56.7%
Halite: 35.1%
Sylvite: 8.2%

Case study 2

Hybrid process for water recovery and energy harvesting from industrial brines

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Case study 3

Simultaneous recovery of resources and water purification in electroplating applications

OBJECTIVE:
The application of a **hybrid high-recovery RO (HRRO)** prototype will demonstrate the recovery of valuable electrolytes and fresh water preservation in a plastic electroplating facility, hosted by BIA. The process is aiming towards recovering **up to 95 % of copper and chromium, 50% of nickel and preserving 65 % of fresh water**.

Die Oberfläche

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Case study 3

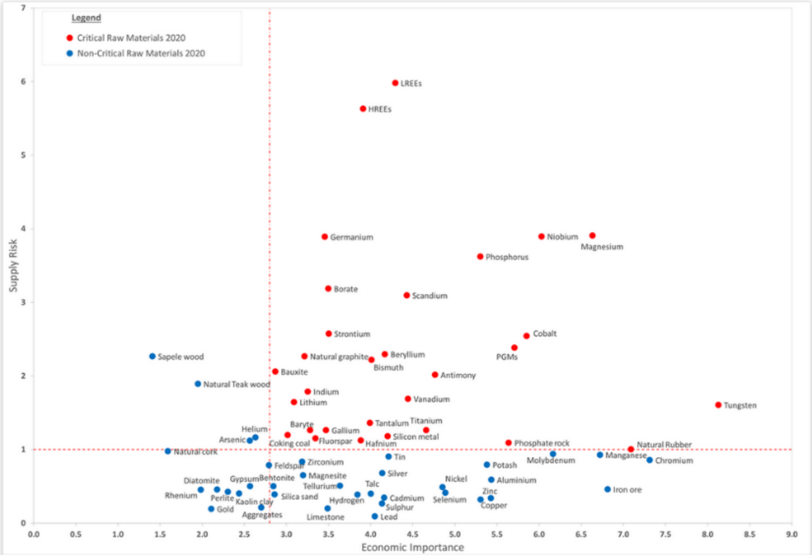
Simultaneous recovery of resources and water purification in electroplating applications

Problem to solve

To reuse ~100% of the water in rinsing baths while recovering for reuse Copper, Nickel and Chromium

Proposed solution

A novel High Recovery Reverse Osmosis system capable of handling all rinsing effluents coupled with an IX treatment



Impact

At the moment the metals that are in the rinsing baths are discharged as toxic wastes while the water is not reclaimed. The impact of the solution is universal to all electroplating industry and the company will benefit economically , environmentally and strategically.

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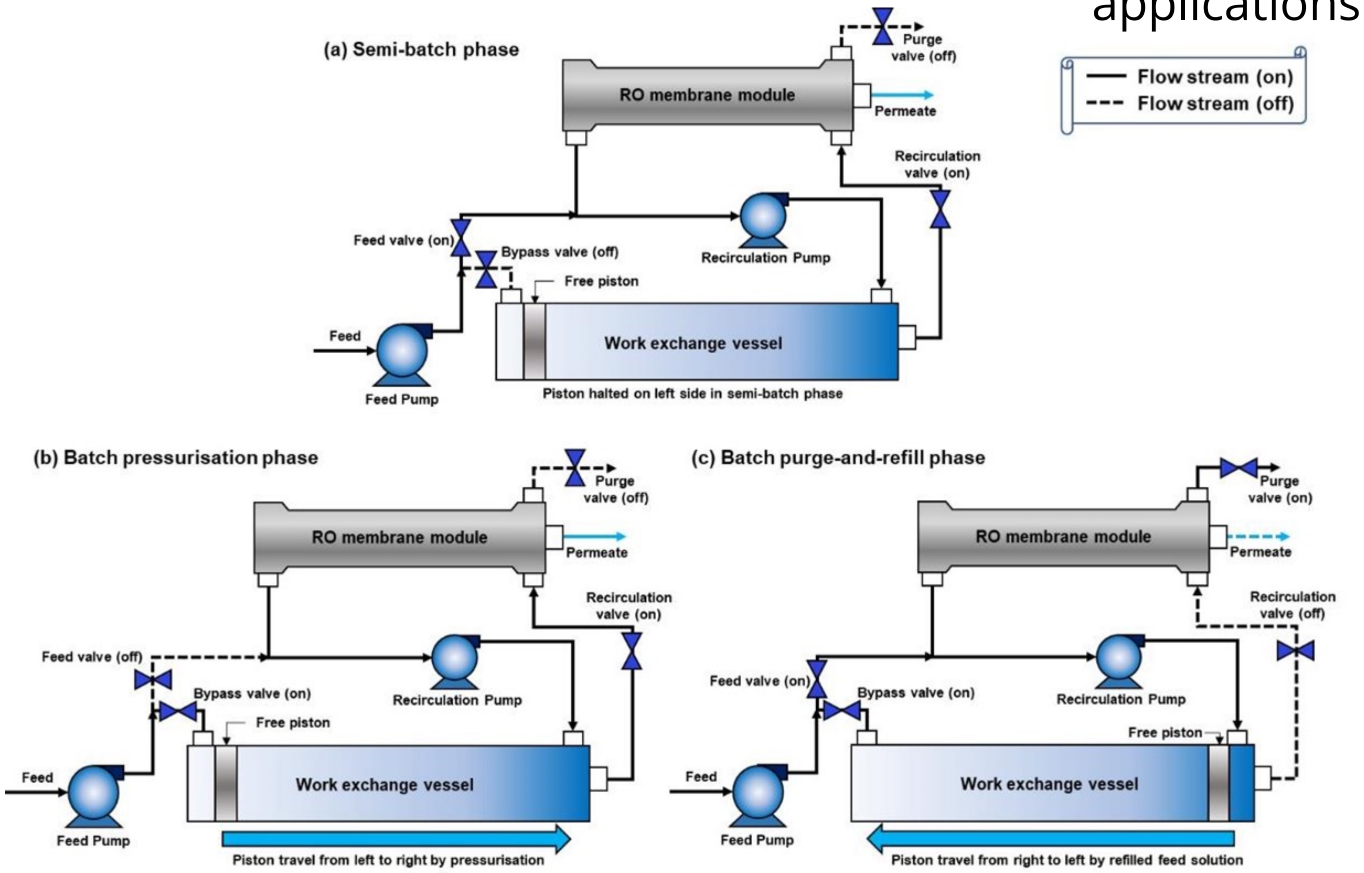
Case study 3

Simultaneous recovery of resources and water purification in electroplating applications



Hybrid semi-batch/batch reverse osmosis (HSBRO) for use in zero liquid discharge (ZLD) applications. Ebrahim Hosseinipour, Somayeh Karimi, Stéphan Barbe, Kiho Park, Philip A.Davies. Desalination Volume 544, 15 December 2022, 116126 https://doi.org/10.1016/j.desal.2022.116126

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Case study 3

Simultaneous recovery of resources and water purification in electroplating applications

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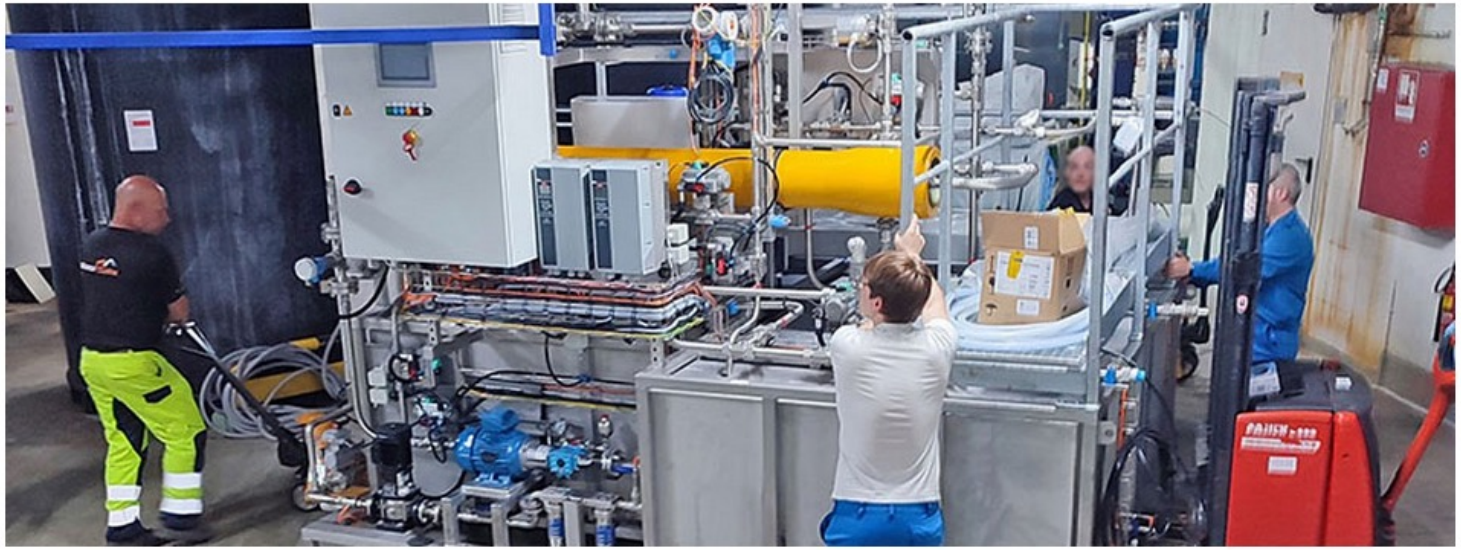
Case study 3

Simultaneous recovery of resources and water purification in electroplating applications

BIA expands water treatment for electroplating line

19-06-2024 CREATED BY OM GALVANIZE BIA



Thanks to the new electroplating wastewater treatment system, BIA can almost completely recover the recyclable materials (Image: BIA)

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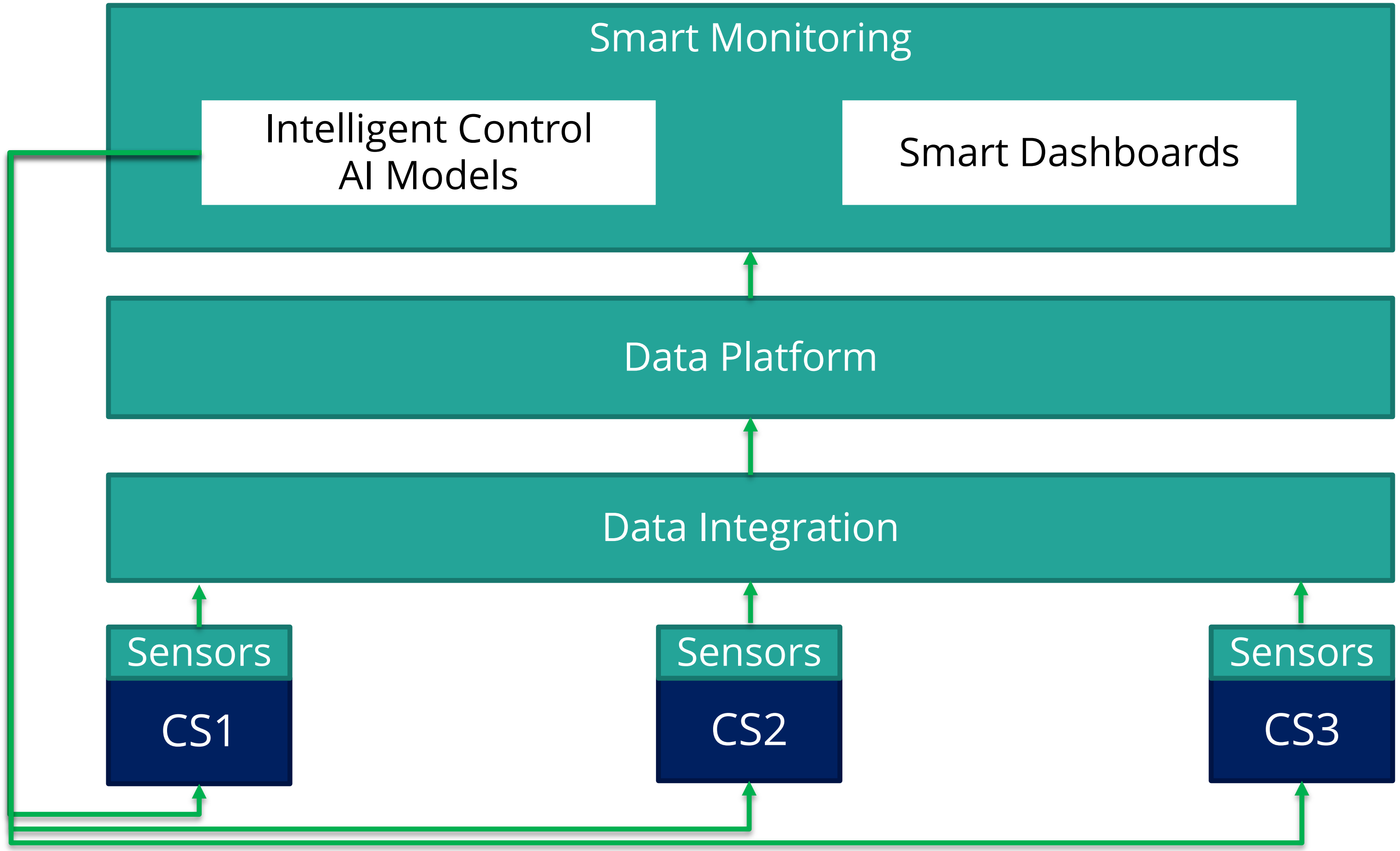
Smart monitoring integration, AI



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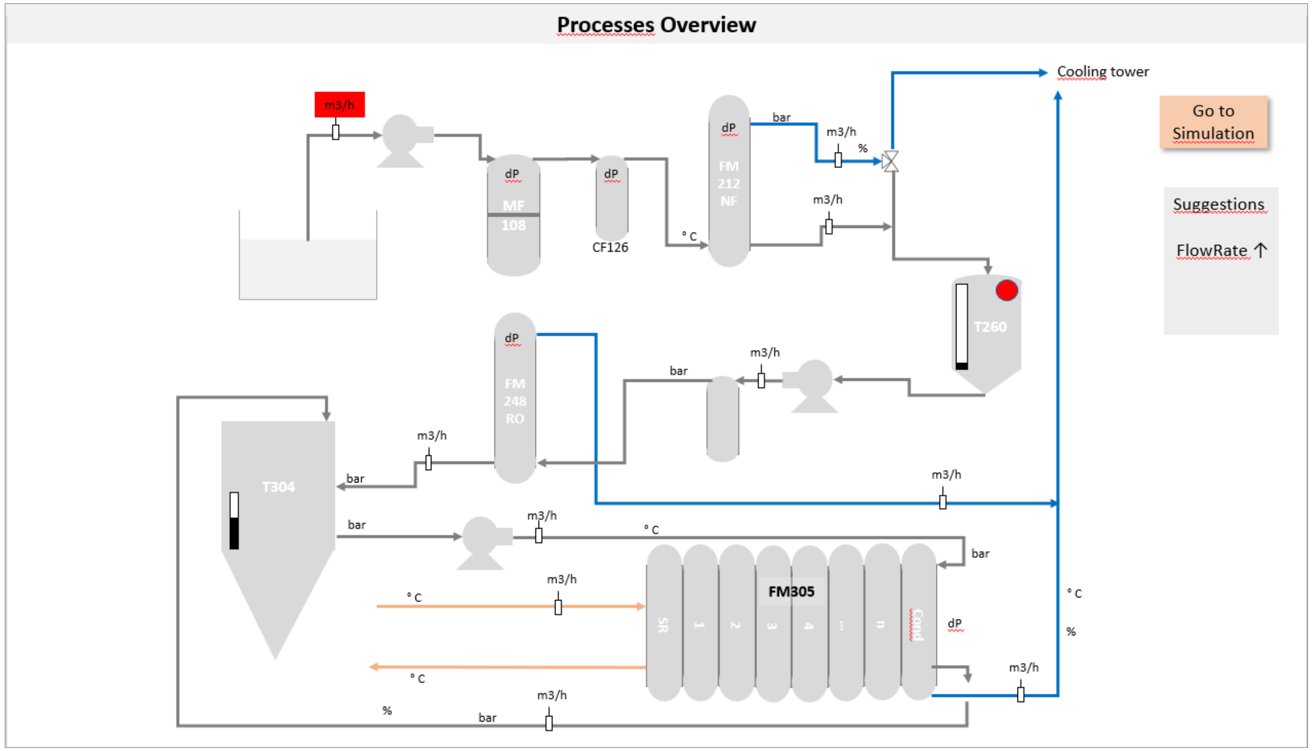
Smart monitoring and Dashboards

The Smart Dashboards collect the data from the case studies and show the current situation. In addition, they collect the output from the Intelligent Control algorithms and present it as suggestions or actions



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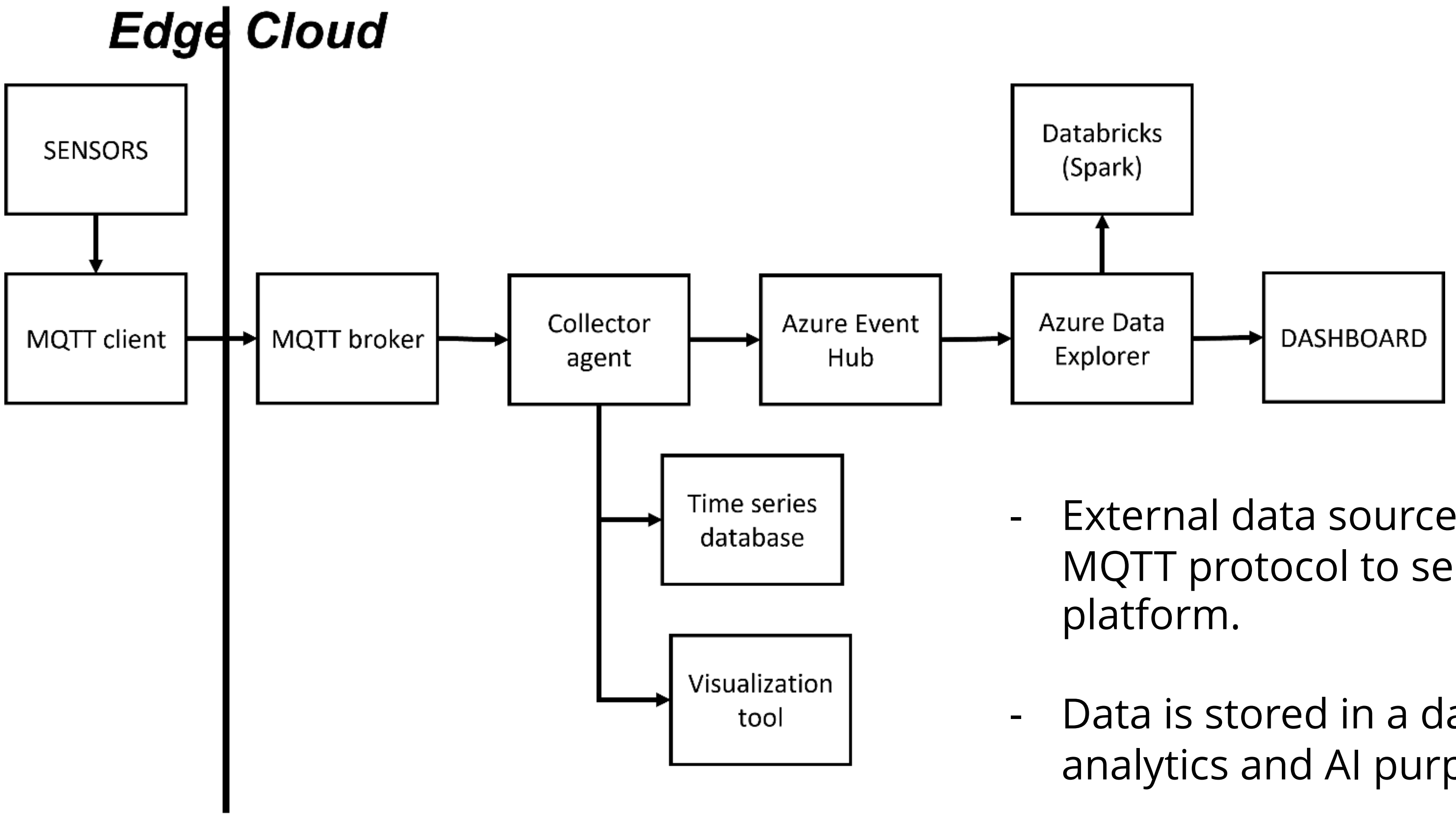
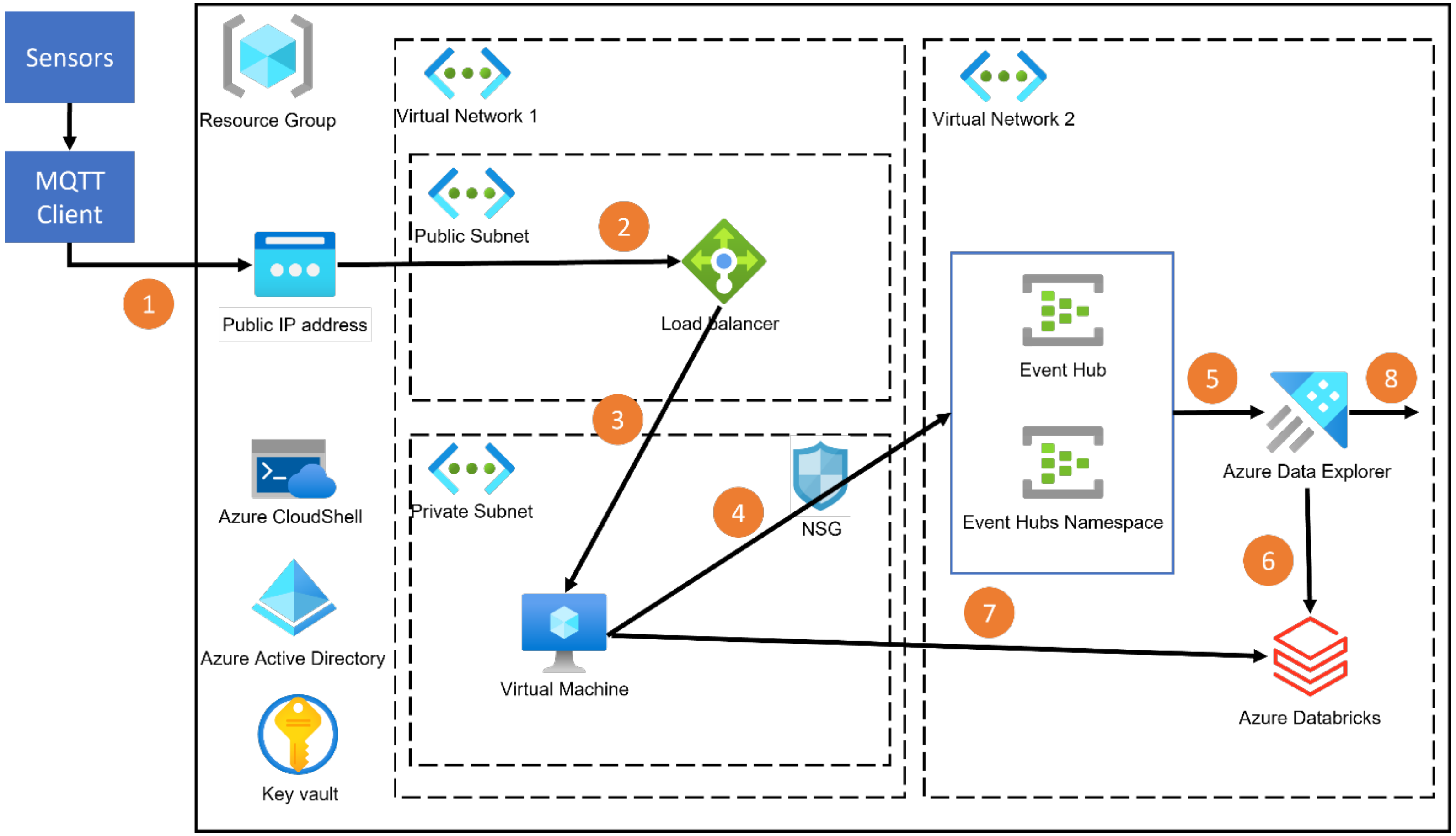
Data acquisition and data platform model



- External data sources from sensor networks use MQTT protocol to send messages to the cloud platform.

- Data is stored in a database for visualization, analytics and AI purposes.

- Historical, real time and metrics visualization is provided using dashboards.



1. The MQTT messages are sent to the IP public address.
2. The TCP traffic from the public IP address reach the Load Balancer, in which the inbound policies and the connection with the VM is allowed.
3. The messages are ingested by the broker installed in the VM.
4. The data received from the broker is sent to the Event Hub deployed in a resource group.
5. Using a connection between the Event Hub and ADX data is stored in a table of the database.
6. Advance data analytics will be performed using Databricks (Spark).
7. Other consumers can use the ADX table to exploit the data. For example, for BI analytics and visualization using Grafana.

Publications

- Energy duty in direct contact membrane distillation of hypersaline brines operating at the water-energy nexus. Enrica Fontananova, Valentina Grosso, Elvira Pantuso, Laura Donato, Gianluca Di Profio. Journal of Membrane Science 676 (2023) 121585 https://doi.org/10.1016/j.memsci.2023.121585
- Hybrid semi-batch/batch reverse osmosis (HSBRO) for use in zero liquid discharge (ZLD) applications. Ebrahim Hosseinipour, Somayeh Karimi, Stéphan Barbe, Kiho Park, Philip A.Davies. Desalination Volume 544, 15 December 2022, 116126 https://doi.org/10.1016/j.desal.2022.116126
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a.sapalidis@inn.demokritos.gr

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