



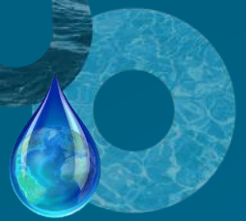
Brine Management and Resource Recovery in the Context of Circular Economy

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School of Chemical Engineering

Unit of Environmental Science and Technology

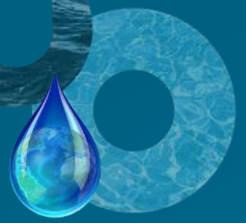


Brine discharge problem

- Brine → high salt concentration in water (mainly NaCl)
- Produced → desalination plants, industry (chemical, coal mine, textiles, food etc)
- Brine discharge → Tones of salts and water are released to surface water bodies, sea or WWTP

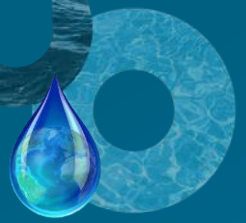
Problems:

- Pollution of surface water bodies and sea (flora and fauna changes, limiting possibility to use river or lake water for agricultural, industrial and municipal purposes creating social, environmental, economical problems)
- Salination of soils (agricultural problems)
- Degradation of underground water bodies
- Accumulation of chlorides and sulfates



Brine recovery

- Tones of recovered salts could be reused by industry (some of them are in the EU list for Critical Raw Materials e.g Mg)
- Other valuable-high market price materials could be recovered apart from salts (such as biomolecules from food industry brines)
- Decrease of energy consumption and CO₂ emissions (less energy is used for the recovery of salts from brines compared to their conventional production)
- Millions of water m³ could be reused for agricultural, industry and municipal purposes.
- Avoid water scarcity
- Better status of soil and water bodies



Strategy

Policy

- EC Strategies
- EC Directives
- European and National Policy
- Suggestions

Design and Development of Circular Brine Treatment Systems

- Desalination Plants
- Chemical Industry
- Extractive Industry
- Textiles
- Urban Wastewater Treatment Plants
- Food Industry

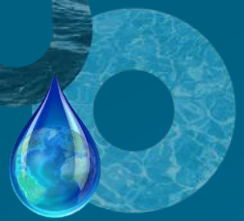
Market Analysis

- Target for products of high value and demand
- Critical Raw Materials
- End of Waste Criteria
- REACH



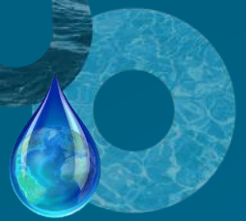
Energy-Environmental aspects

- Environmental Designing
- CO₂ emissions
- Coupling Systems with waste heat
- Coupling Systems with renewable energy sources



Timeline of UEST European Projects





Sol Brine-General Information

“Development of an advanced innovative energy autonomous system for the treatment of brine from seawater desalination plants”



Area of implementation: Tinos Island,
Greece

Project Budget:
1,209,689.00 €

EC Funding (LIFE+):
604,844.00 €

Duration:
39 months

Start date:
01/10/2010

End date:
31/12/2013



**Municipality of Tinos Island
(Project Coordinator)**

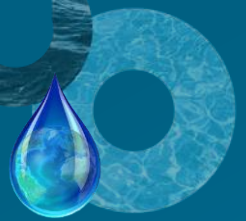


**National Technical University of
Athens**



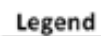
Culligan Hellas S.A.

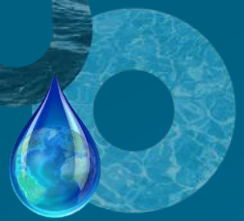




Innovative aspects

- **Total brine elimination:** The system has been designed in line with the Zero Liquid Discharge principle
- **Water Recovery:** (> 90%)
- **Production of useful end-products.** (a) water of high quality and (b) dry salt. Products with market opportunities.
- **Energy autonomous operation:** Solar thermal collectors are used for delivering hot water and a PV for electricity. All energy requirements are covered exclusively through the use of solar energy.
- **Use of state-of the art technology:** Custom designed vacuum evaporation technology (evaporator and crystallizer) and solar dryer.





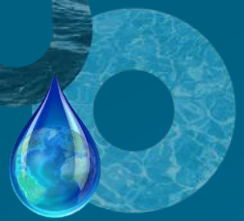
Pilot



Evaporator



Crystallizer



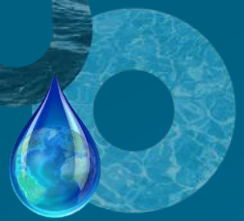
Pilot



Dryer



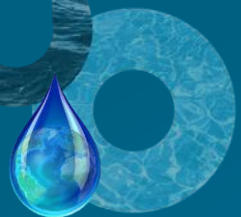
System



Pilot



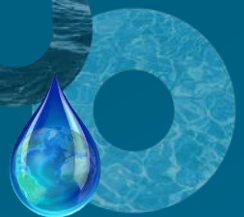
Site Visit



Sol Brine-EU Green Awards

The Best Life Project of last 25 years





Zero Brine



“Re-designing the value and supply chain of water and minerals: a circular economy approach for the recovery of resources from saline impaired effluent (brine) generated by process industries”

Area of implementation: The Netherlands, Spain, Poland, Turkey

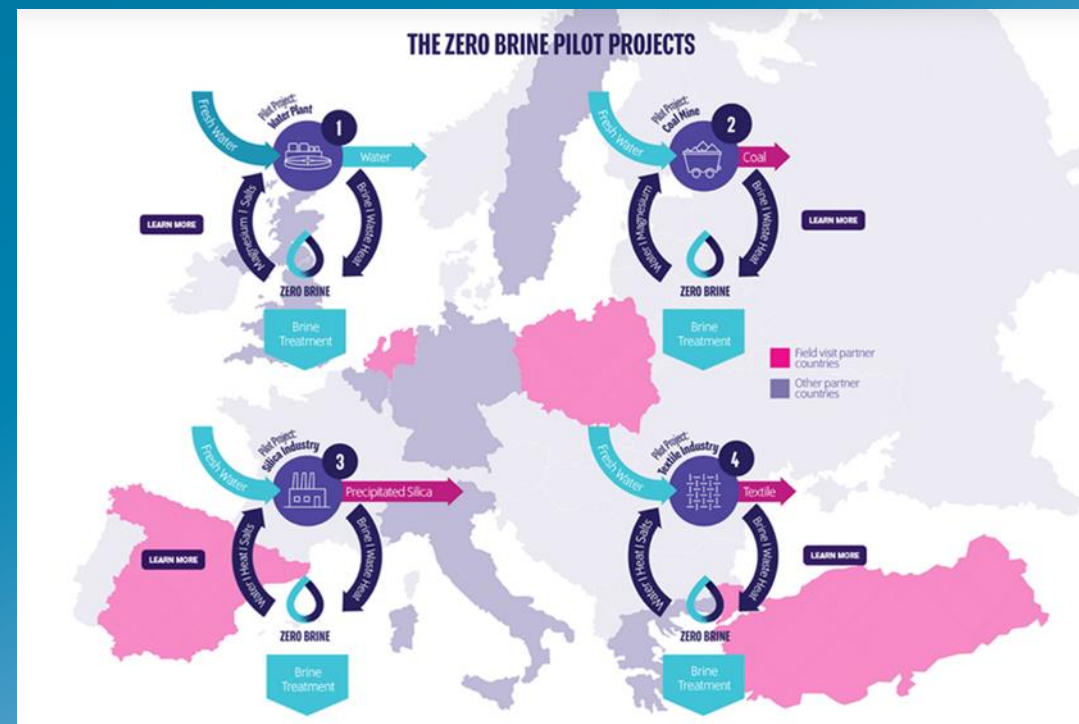
Project Budget:
11,078,222 €

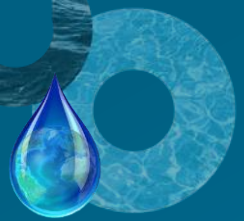
EC Funding:
9,992,209 €

Duration:
54 months

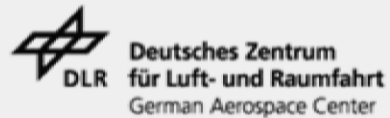
Start date:
01/06/2017

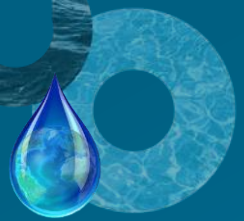
End date:
30/11/2021





Zero Brine-Partners





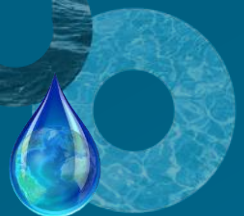
NL Pilot in Demineralised Water Plant EVIDES

“EVIDES provides tones of drinking water and water for industrial use in the Netherlands. Tones of brines from its demineralized processes are discharged in Rotterdam port sea”

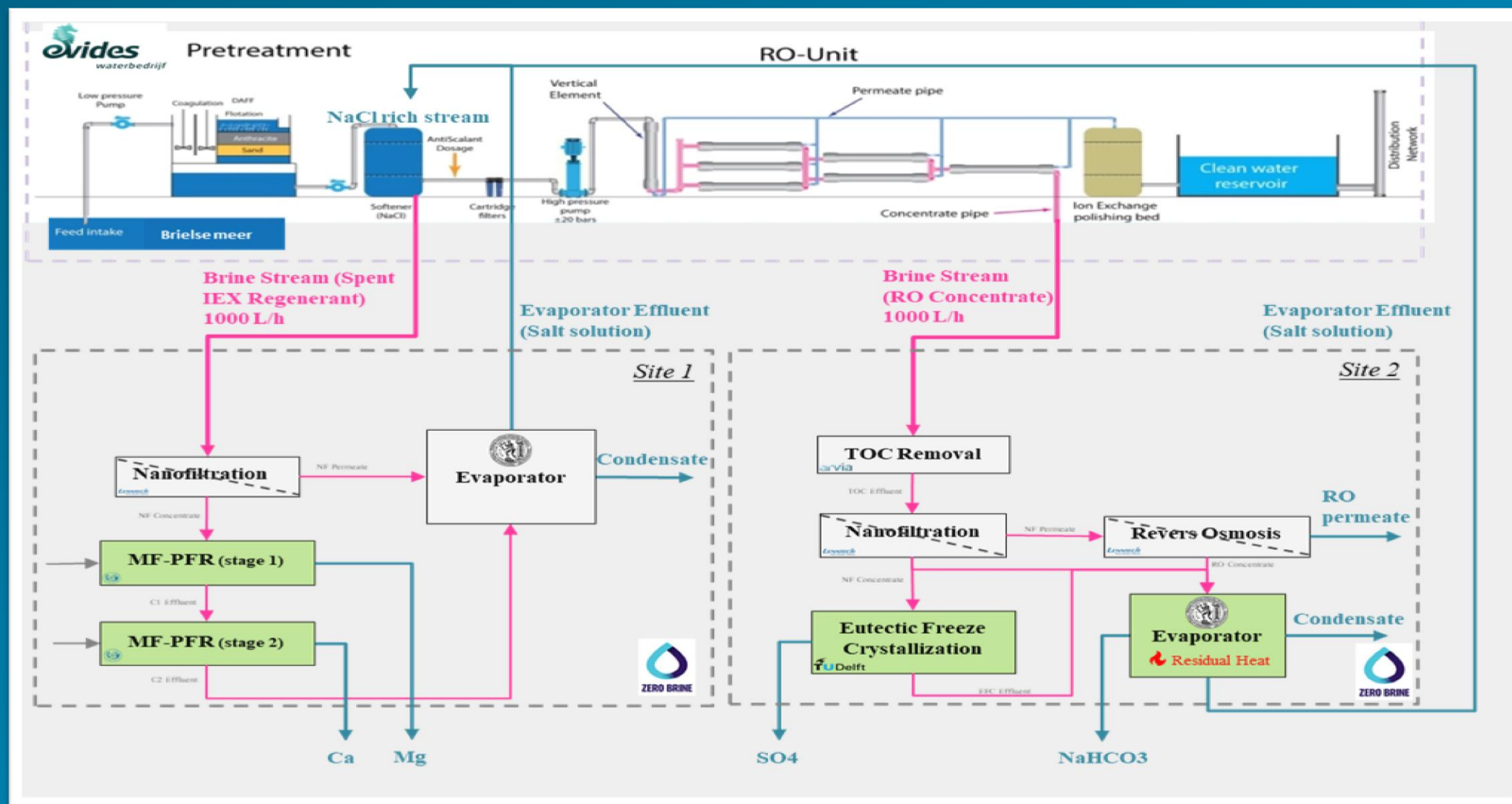


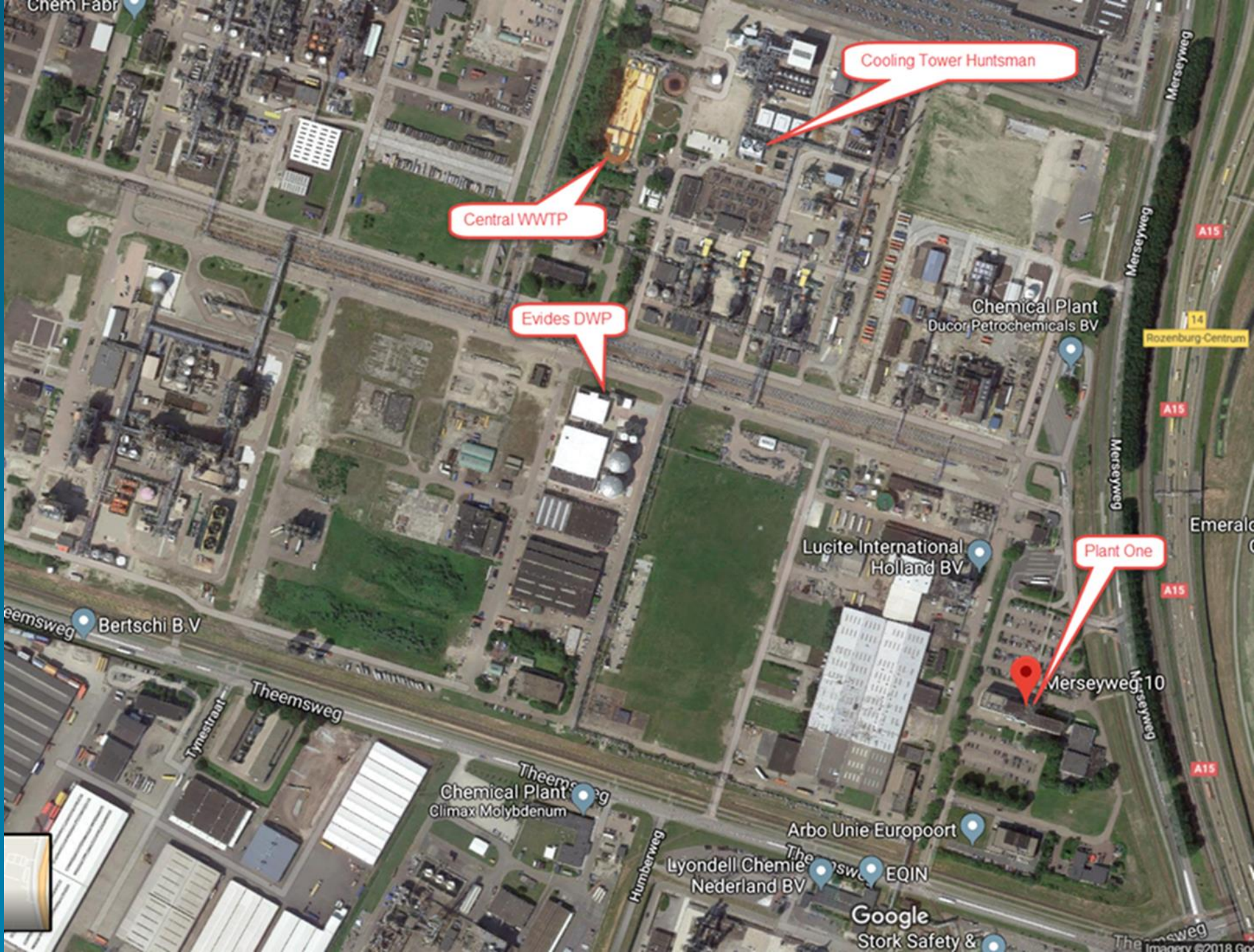
- Magnesium and Calcium from brine
- Sulphates removal
- NaHCO_3
- High quality water
- High concentration and high-purity NaCl solution which will be used for the regeneration of EVIDES ion exchange resins
- Circular economy model





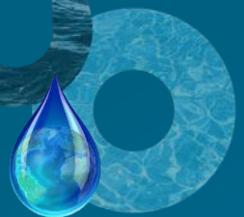
NL Pilot Process Flow Diagram





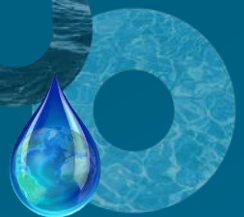
NL Pilot





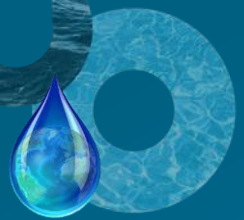
NL Pilot





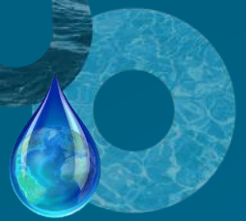
NL Pilot





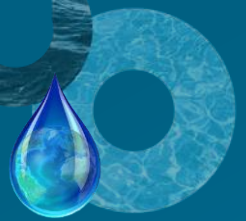
NL Pilot





NL Pilot results

- Ca and Mg removal of around 93%
- Purity of recovered Mg crystals is 84-90% and Ca crystals is 93-99%
- Water recovery of about 90%
- Quality improvement of end products would have positive impact on annual revenues (3,000,000-8,000,000 €/year)
- Avoiding environmental penalties due to brine discharge
- Internal valorization of NaCl solution

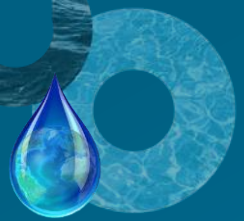


ES Pilot Silica Industry

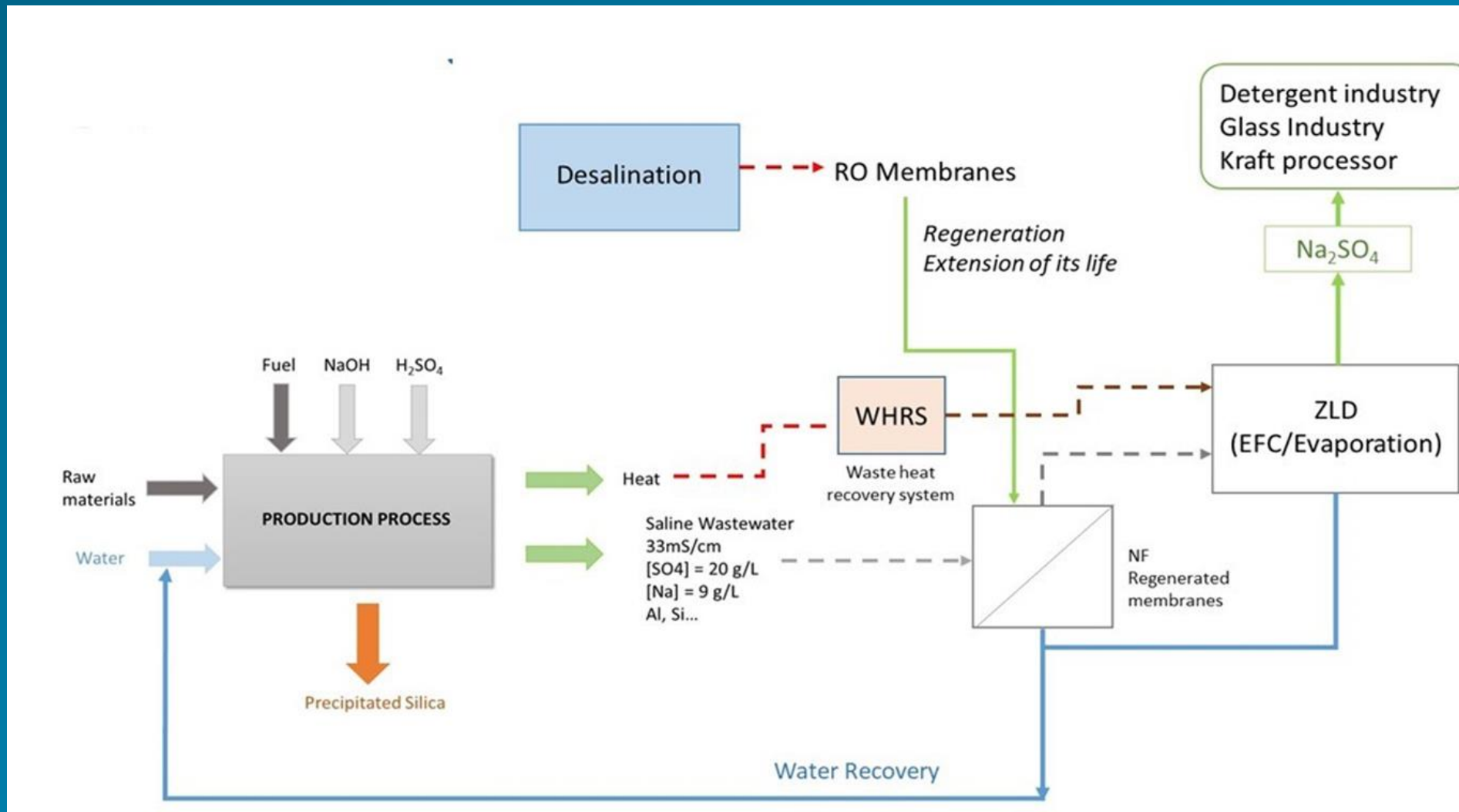
“IQE produces a brine with high concentrations of NaCl, sulphates, color and impurities”

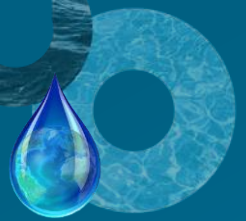


- Na_2SO_4 recovery
- Clean water to be reused in the procedure
- System coupling with waste heat
- Circular economy model



ES Pilot Process Flow Diagram

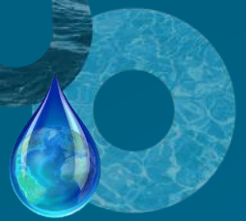




ES Pilot Results

- 0,9 m³ of water recovered / m³ of wastewater treated
- 20 kg of Na₂SO₄ / m³ of wastewater (about 90 %)
- Use of waste heat
- Economic benefits
- Environmental benefits (water consumption reduction at IQE: >70%)



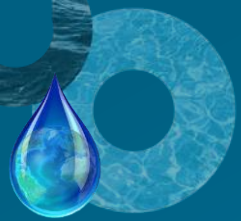


PL Pilot Mining Industry

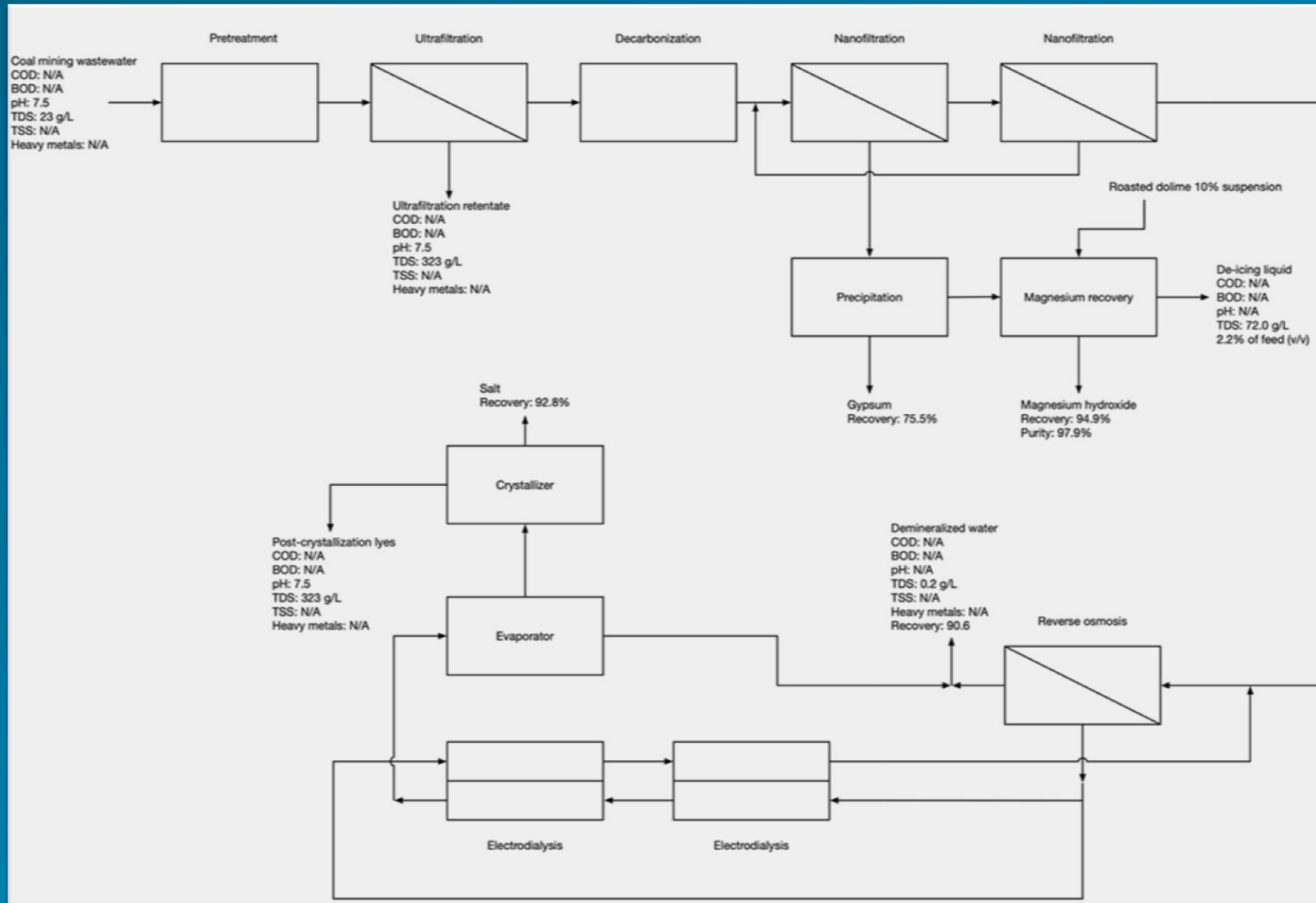
“PGG, the company that owns most of the coal mines in Poland, produces tones of brine per year during the extraction process. This high salinity brine is discharged in artificial ponds for precipitation of salts and solids. However, high salinity water flows through small rivers to Vistula river, resulting in severe status degradation of the river. ”

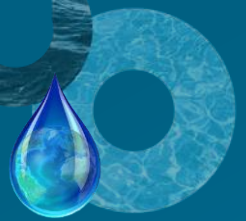


- Magnesium hydroxide
- NaCl
- Gypsum
- High quality water



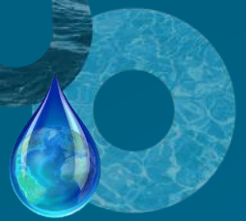
PL Pilot Process Flow Diagram





PL Pilot Results

- Energy consumption: 11.2 kWh/m³ of treated brine (16.7 kWh/m³ for reference technology)
- Salt recovery: 92.8 % (81.0 % for reference technology)
- Magnesium hydroxide recovery: 94.9 % (0 % for reference technology)
- Water recovery: 90.6 %



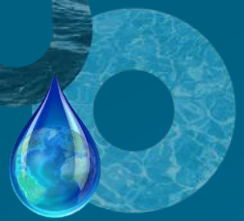
TK Pilot, Textiles

“Zorlu group produce tones of effluents of high organic content, color and salts. This content makes these effluents very toxic.”

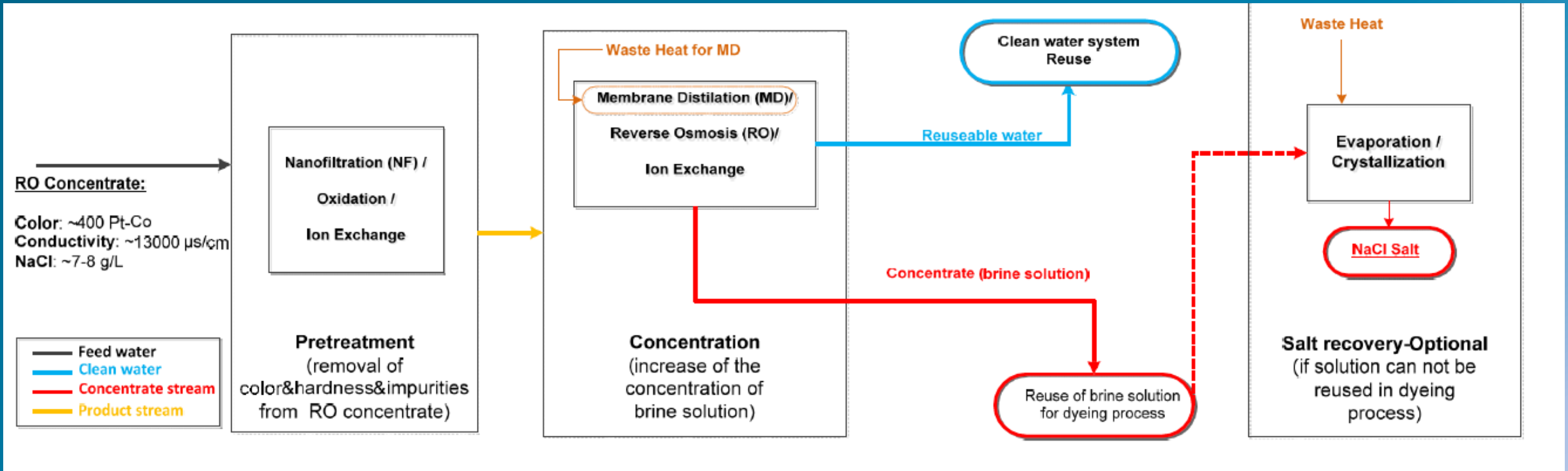


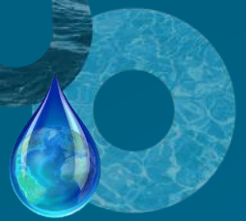
- Reusable water
- NaCl
- Concentrated brine for reuse in dyeing process





TK Pilot Process Flow Diagram





Brine Excellence Centers (BEC)

- ✓ Netherlands, Poland, Italy, Greece and Spain
- ✓ Shared use of technologies
- ✓ Shift towards replication roadmap and activities
- ✓ Three follow-up projects
- ✓ Simulation software at DLR online available



Greece BEC
National Technical
University of Athens



The Netherlands BEC
DELFT University of
Technology



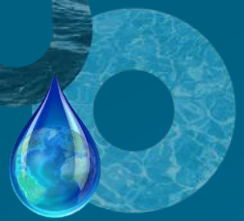
ITALY BEC
University of
Palermo



SPAIN
Eurecat

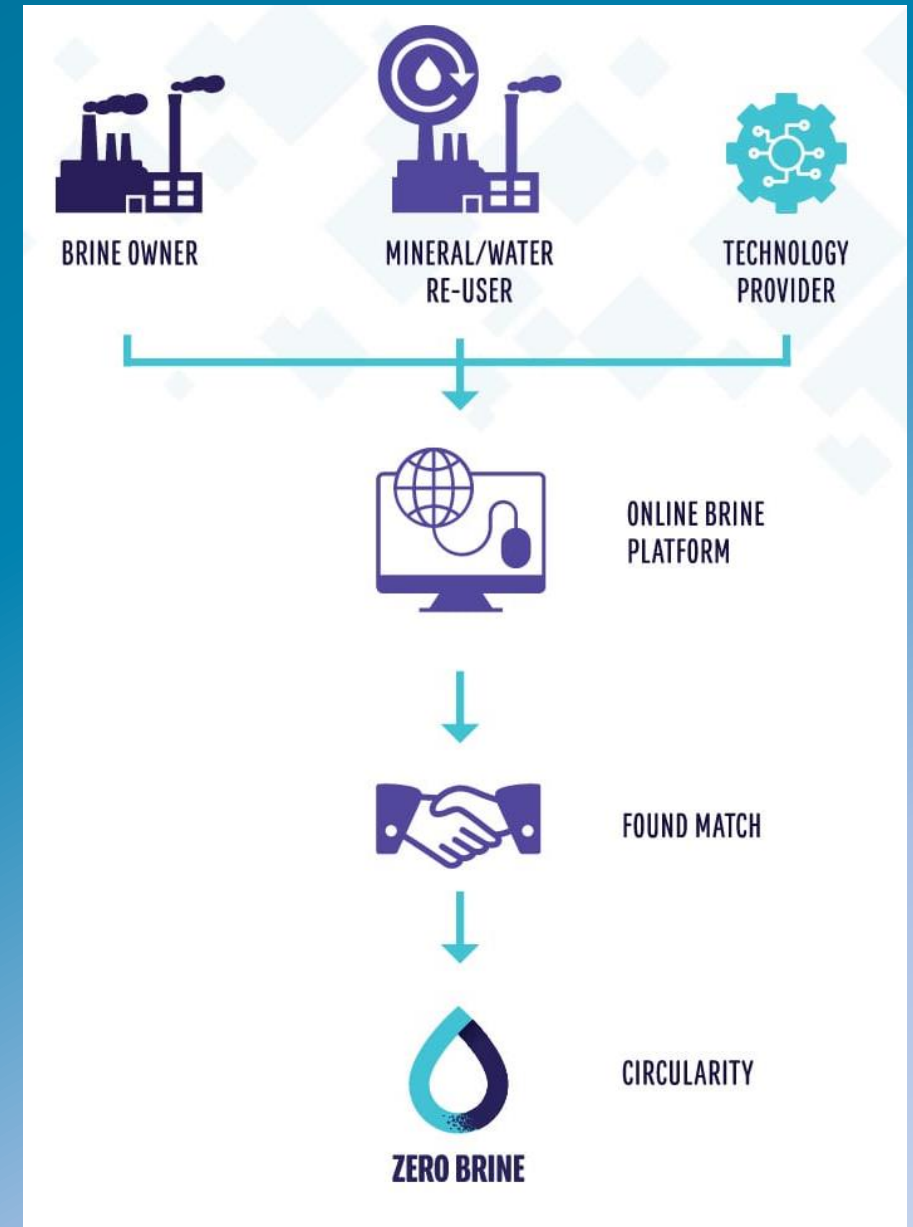


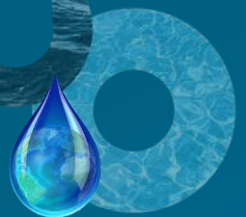
POLAND BEC
Silesian University of
Technology



Online Brine Platform developed by NTUA

- On-line matchmaking of
 - brine owners with technology providers
 - brine owners with salts or water end users
- Database with more than 200 brine producers in the Netherlands
- Salt users from 5 large industrial clusters are registered
- Workshops about OBP and Zero Brine results in the Netherlands, Italy, Spain, Poland
- Athens Workshop: Zero Brine results, OBP registration and use by stakeholders in Greece and Cyprus





Brine Mining-General Information

“Demonstration of an advanced technique for eliminating coal mine wastewater (brines) combined with resource recovery”



Area of implementation: Poland

Project Budget:
6,383,847 €

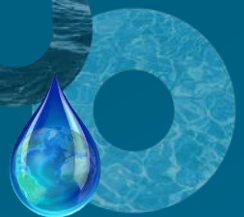
EC Funding (LIFE+):
3,508,365 €

Duration:
54 months

Start date:
01/10/2019

End date:
1/03/2024





Partners

Coordinating beneficiary



National Technical
University of Athens



Beneficiaries



GLOWNY INSTYTUT
GORNICZA



LENNTECH



NEVIS-NOVEL
Environmental Solutions S.A.



SEALEAU B.V.



Silesian University of Technology



POLSKA GRUPA GORNICZA

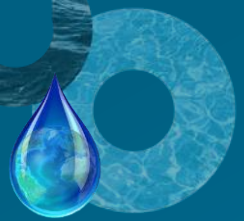


THERMOSSOL STEAMBOILERS S.A.



Titan Salt B.V.

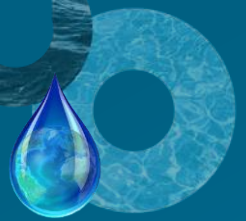




The problem

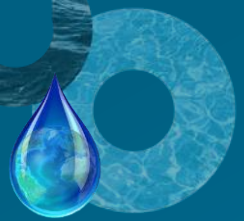
- EC aims to eliminate the electricity production from extracted coal.
- The total hard coal production in Europe in 2015 is 100 Mtones.
- Poland is the dominant producer in EU (approximately 72% of total European production).
- Coal mines generate vast amounts of saline water.
- Direct or indirect drainage of these streams to water bodies.
- Ecological status of rivers: moderate.
- Vistula river: 55% of fresh water in Poland
- Vistula salination: 150-200 million \$ per year (losses in industry, agriculture and water transport).



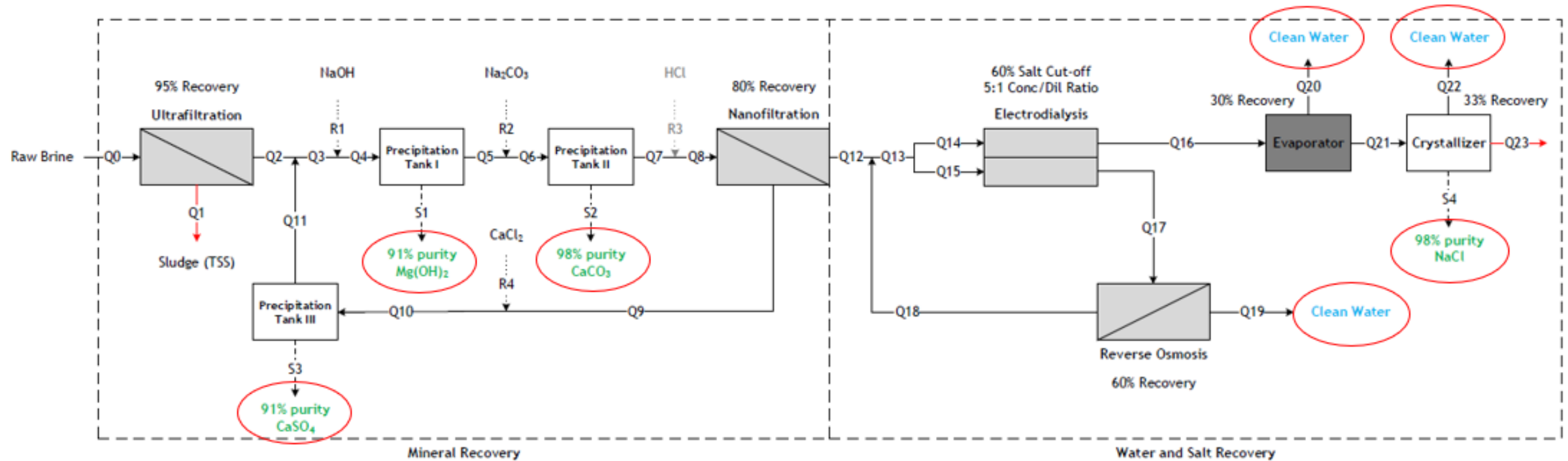


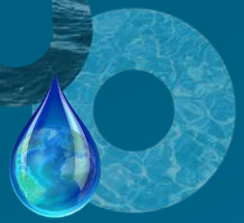
Main Objectives

- Economically viable, innovative system for the elimination and full recovery of resources included in the coal mining brines.
- A system able to treat and directly recover end-products (minerals/salts and water) of high quality and purity.
- End-products that satisfy market specifications.
- Water Framework Directive (WFD) and the Circular Economy package
- To decrease the energy consumption compared to current best practice

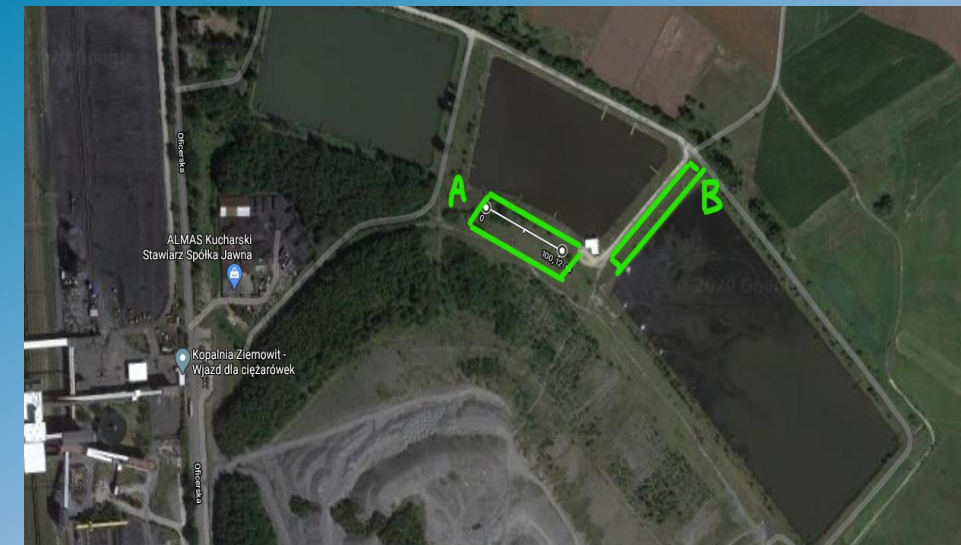
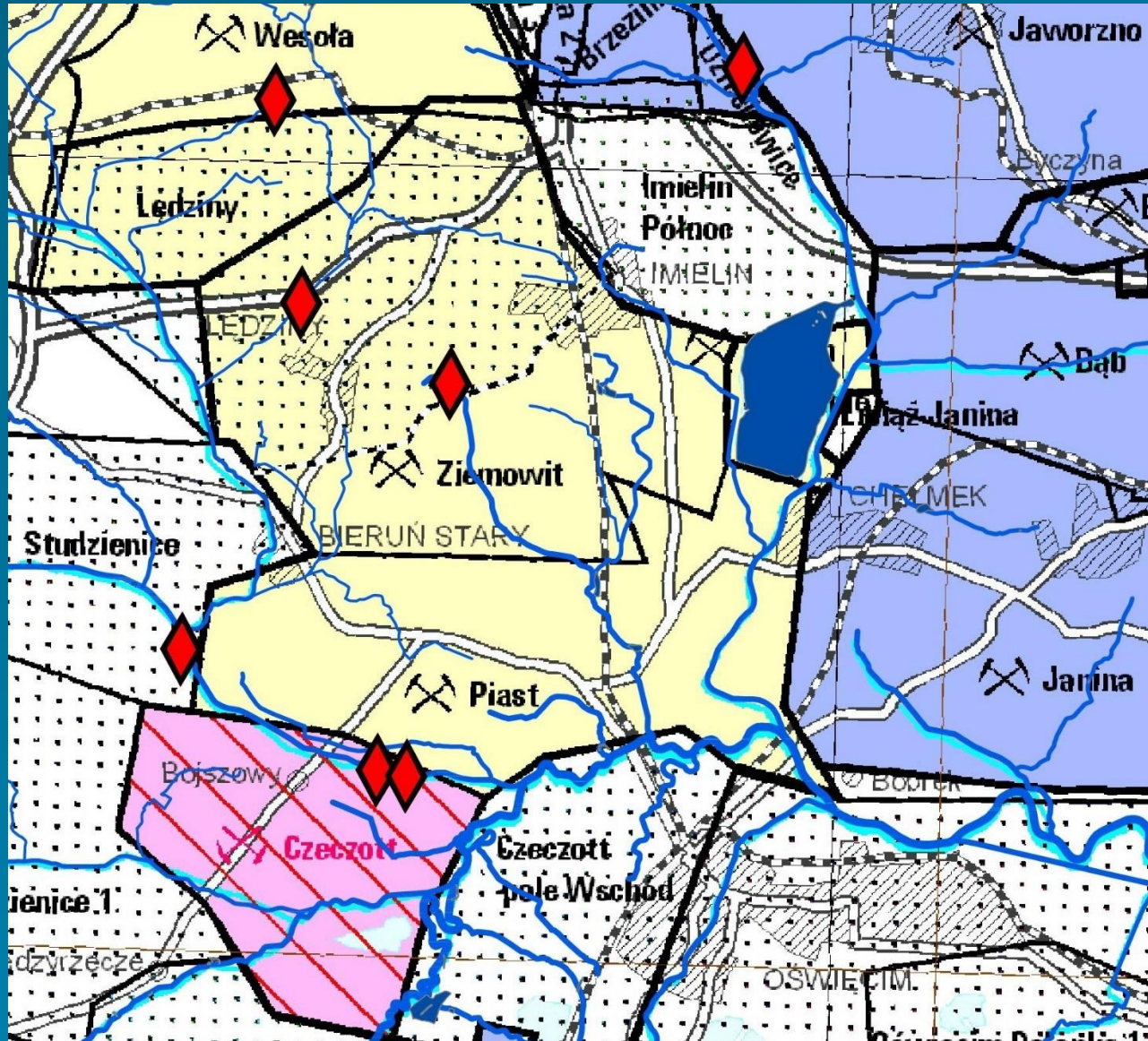


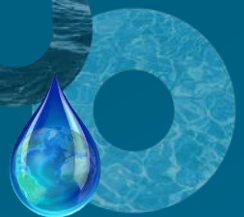
Process Flow Diagram





Demonstration of plant location





Water Mining-General Information

*“Next generation water-smart management systems:
large scale demonstrations for a circular economy and society”*



38 partners

Area of implementation:
The Netherlands, Italy, Spain, Cyprus

Project Budget:
19,097,946 €

EC Funding (LIFE+):
16,876,959 €

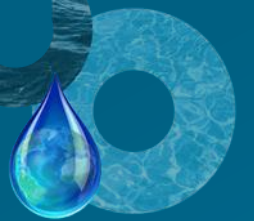
Duration:
48 months

Start date:
01/09/2020

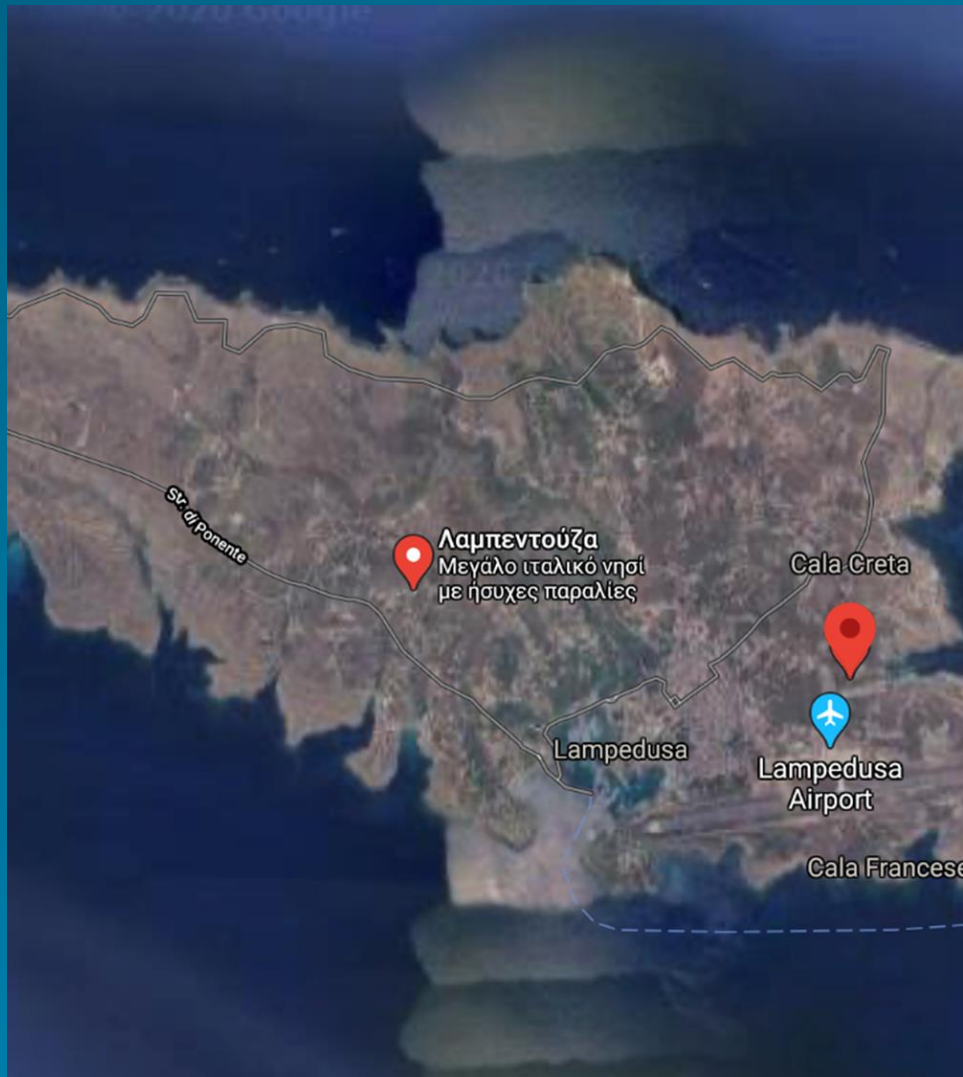
End date:
31/08/2024



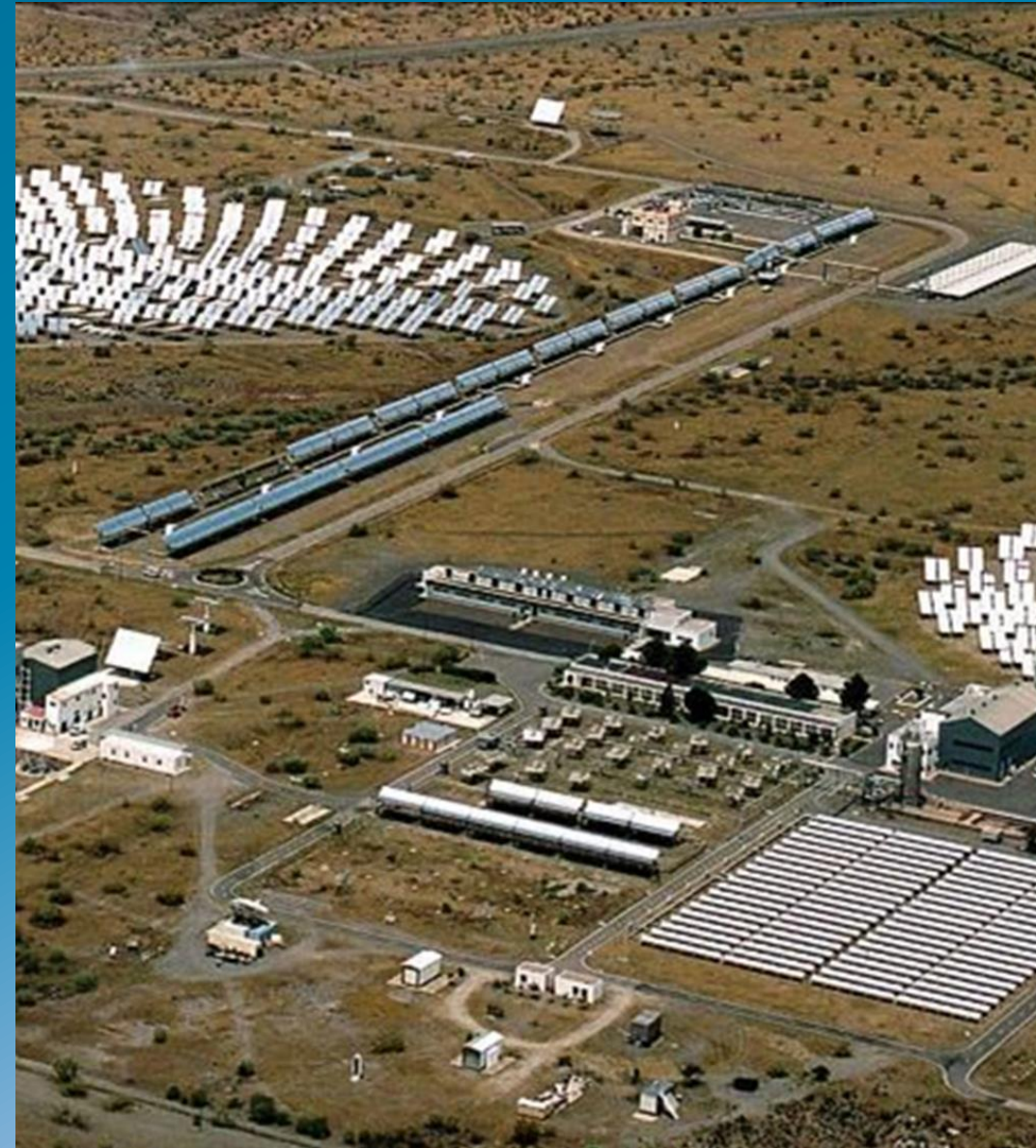
- [illegible]



Desalination and sustainable brine management



PSA SPAIN

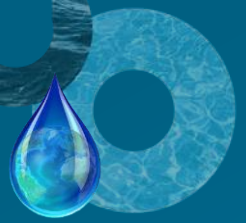


SELIS
Lampendusa



Desalination and sustainable brine management targets

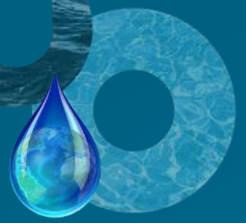
- 50% of energy requirements will be covered by renewable energy,
- water recovery $\geq 90 \%$,
- magnesium purity $> 90 \%$,
- sodium chloride purity $> 90 \%$
- reduced energy requirements for seawater desalination process by 25-30 %,



Demonstration for phosphorus, water, salt and energy recovery from urban wastewater

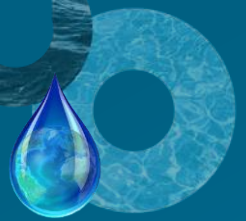
(LARNACA-Cyprus, ACSA-Spain)





Demonstration for phosphorus, water, salt and energy recovery from urban wastewater

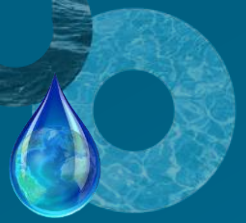
- Phosphorus recovery.
- Mg, Ca, and NaCl recovery.
- High-quality water
- Anaerobic digestion as a cost-effective technology to recover energy (as biogas).
- Two-stage biological process, performing partial nitrification and anammox as a cost-effective alternative to remove nitrogen at mainstream conditions.



Demonstration of extraction/valorization of Kaumera Nereda Gum

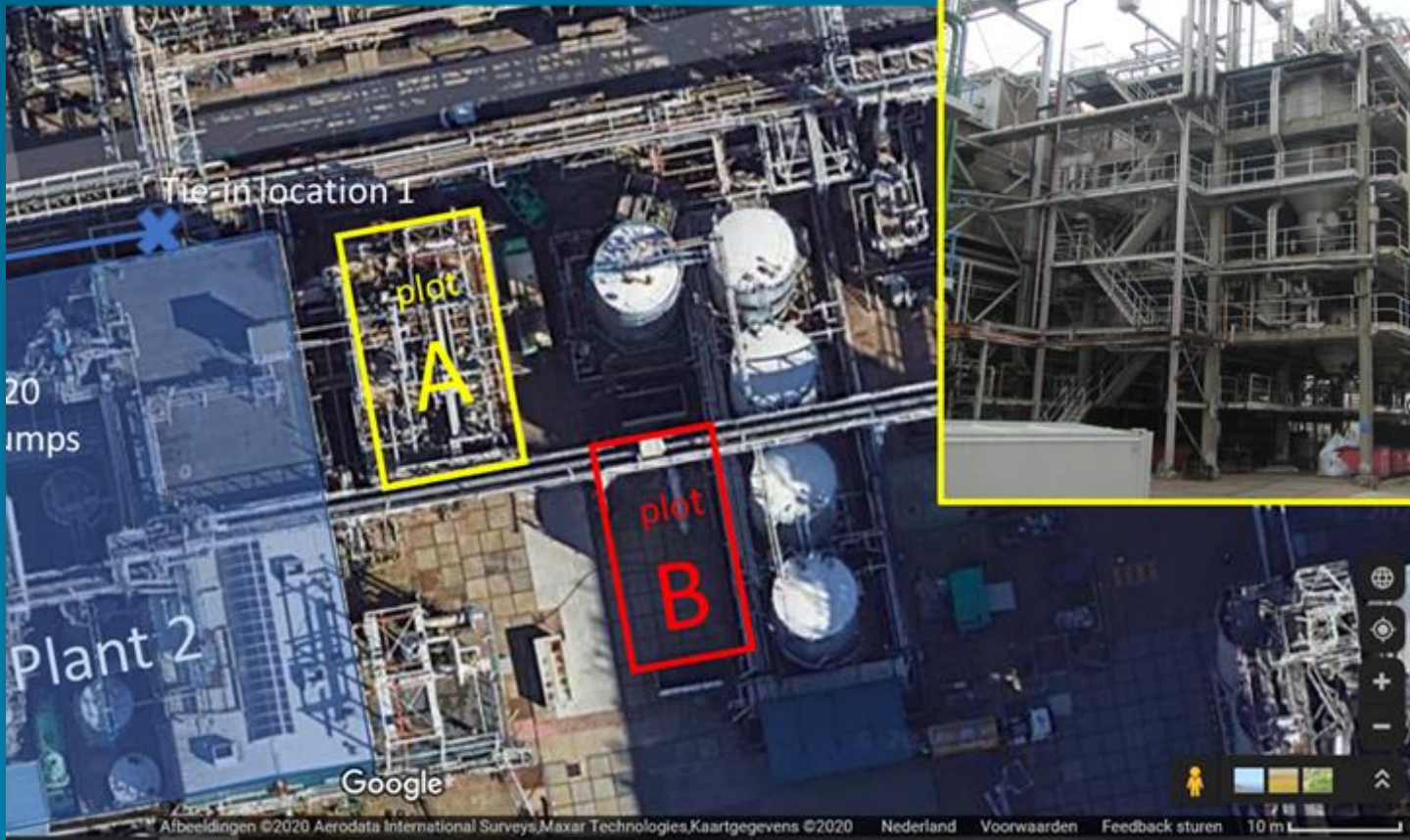


- Kaumera polymer extraction
- water recovery > 90 %
- Production of CH₄ gas
- Phosphorus recovery



Closed-loop water recovery in Industrial sector

(Hexion-The Netherlands, Sugar Industry-India)



- Water recovery
- Waste heat recovery
- > 90 % NaCl recycling back to the production processes

Way forward in brine management and circular economy.

Gained knowledge could be applied on a large-scale sea water desalination project
(demo capacity > 100 m³/day)



Thank you for your attention!

Prof. Maria Loizidou

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School of Chemical Engineering

National Technical University of Athens

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