

European Twinning for research in Solar energy to (2) water (H<sub>2</sub>O) production and treatment technologies  
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European Research Executive Agency REA.C3



Funded by  
the European Union

# Sol2H2O



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INSTITUTO TECNOLÓGICO  
DE CANARIAS



Gobierno  
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# Fast Track School #2

Introduction to Solar-driven Water production & Treatment technologies and brine treatment processes  
Beyond State of the Art

POZO IZQUIERDO, 25.-26.09.2024



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Giorgio Micale

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## Brine treatment processes for raw materials recovery and Zero Liquid Discharge (ZLD)

POZO IZQUIERDO, 25.-26.09.2024

# Brine treatment processes for raw materials recovery and Zero Liquid Discharge (ZLD)

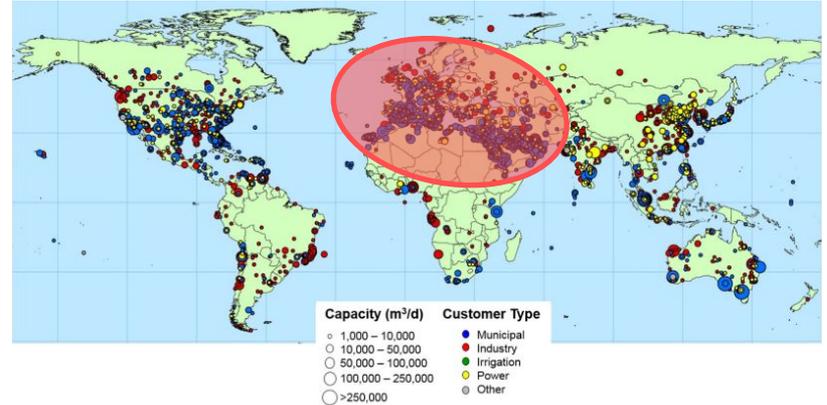
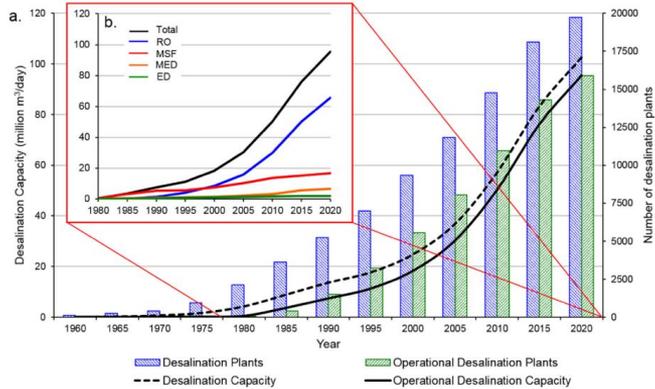
Brine  
production: a  
global outlook

Example 1 –  
The  
SEArcularMINE  
project

Example 2 –  
The Water  
Mining project

Example 3 –  
The ReWaise  
project

# Brine production: a global outlook



Total **fresh water** production 65.5 Mm<sup>3</sup>/day (RO plants)

Total **brine** production 90 Mm<sup>3</sup>/day (Industrial waste brine from RO)

More than **50%** of total RO desalination capacity is installed in the **Mediterranean basin**

Typical **brine composition:**

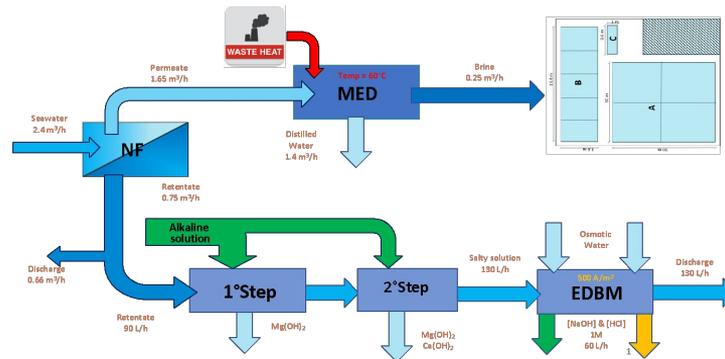
Typical Ions concentration in industrial waste Brine [g/L]					
Na <sup>+</sup>	K	Ca <sup>2+</sup>	Mg <sup>2+</sup>		Cl <sup>-</sup>
21.4	0.8	0.9	2.7	5.5	39



Potential Magnesium Hydroxide production

**290 kton/day**

# 3 examples of brine treatment chains



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# Example 1

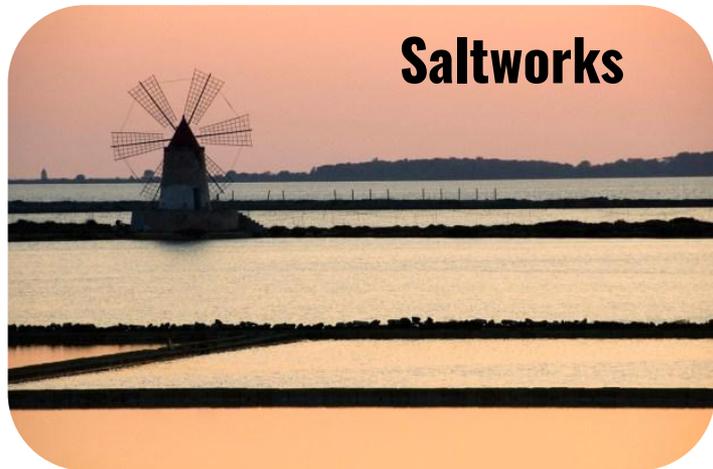
## The SEArCularMINE project



This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 869467.

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# SEArctularMINE context



**Saltworks**

Seawater goes through **natural evaporation and crystallization** in shallow basins ..



.. to produce **sea salt**.



The resulting brine (bittern) is usually returned to the sea.

# Project Overview

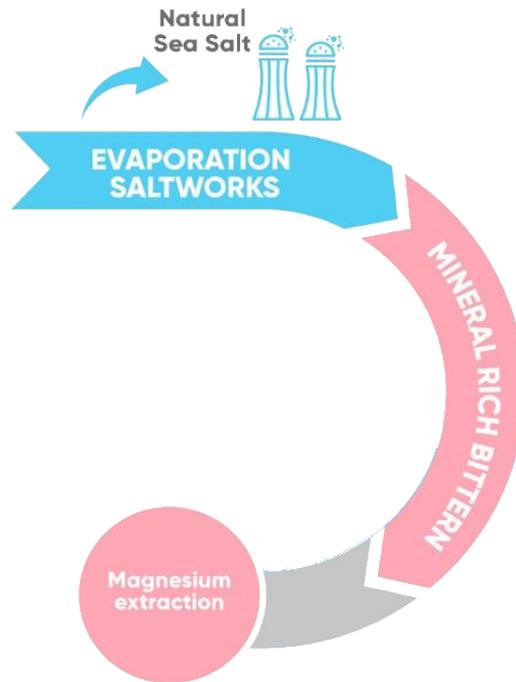


The city of Trapani and its saltworks (highlighted in yellow)



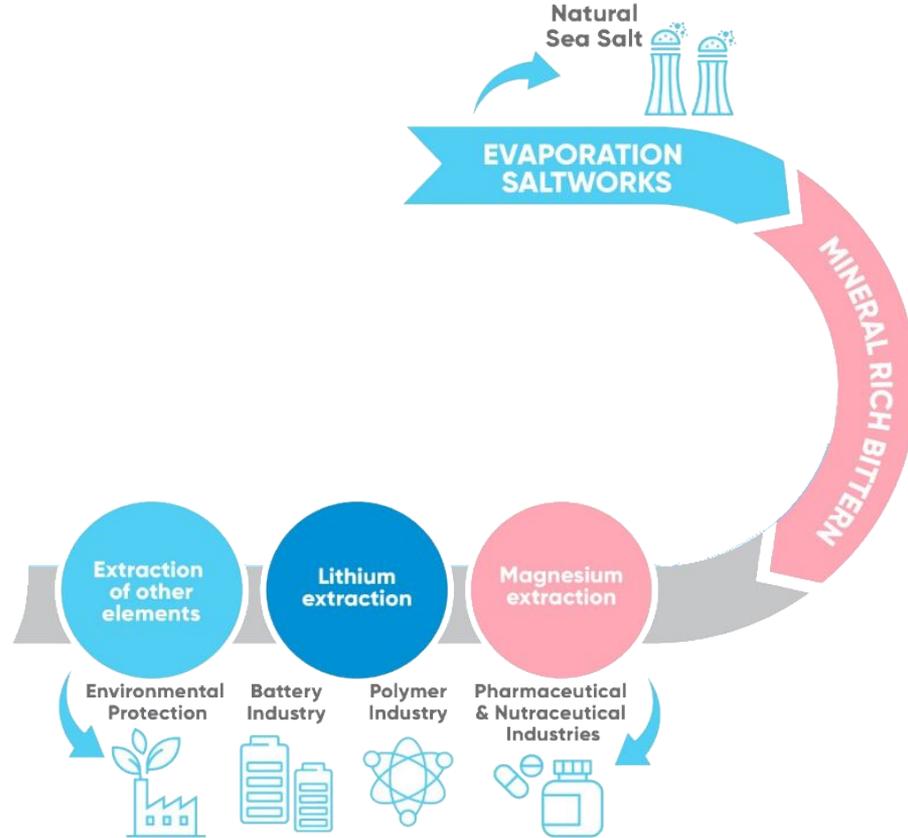
From the original seawater circular mining concept to the integrated pilot plant

# Project Overview



From the original seawater circular mining concept to the integrated pilot plant

# Project Overview



From the original seawater circular mining concept to the integrated pilot plant

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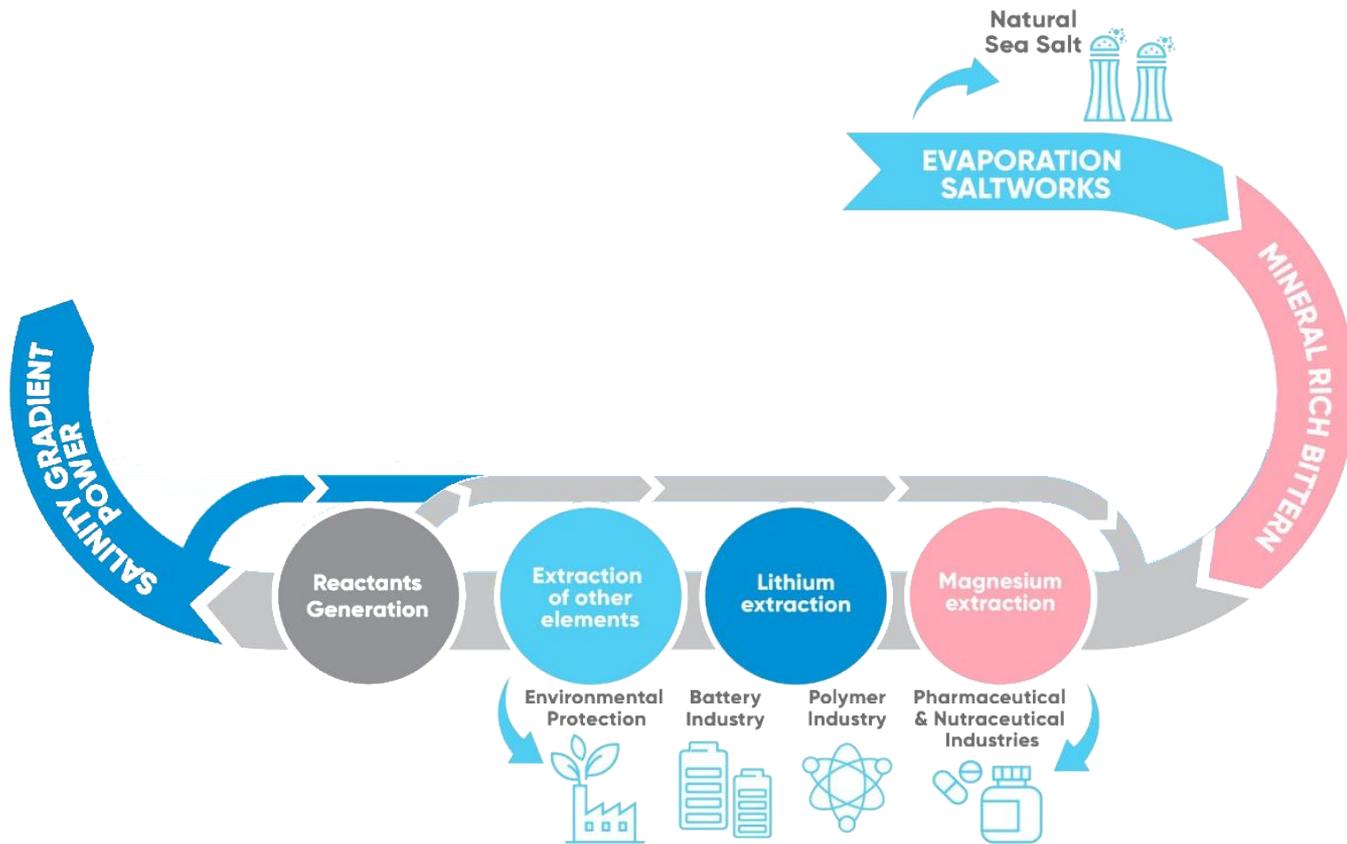


From the original seawater circular mining concept to the integrated pilot plant

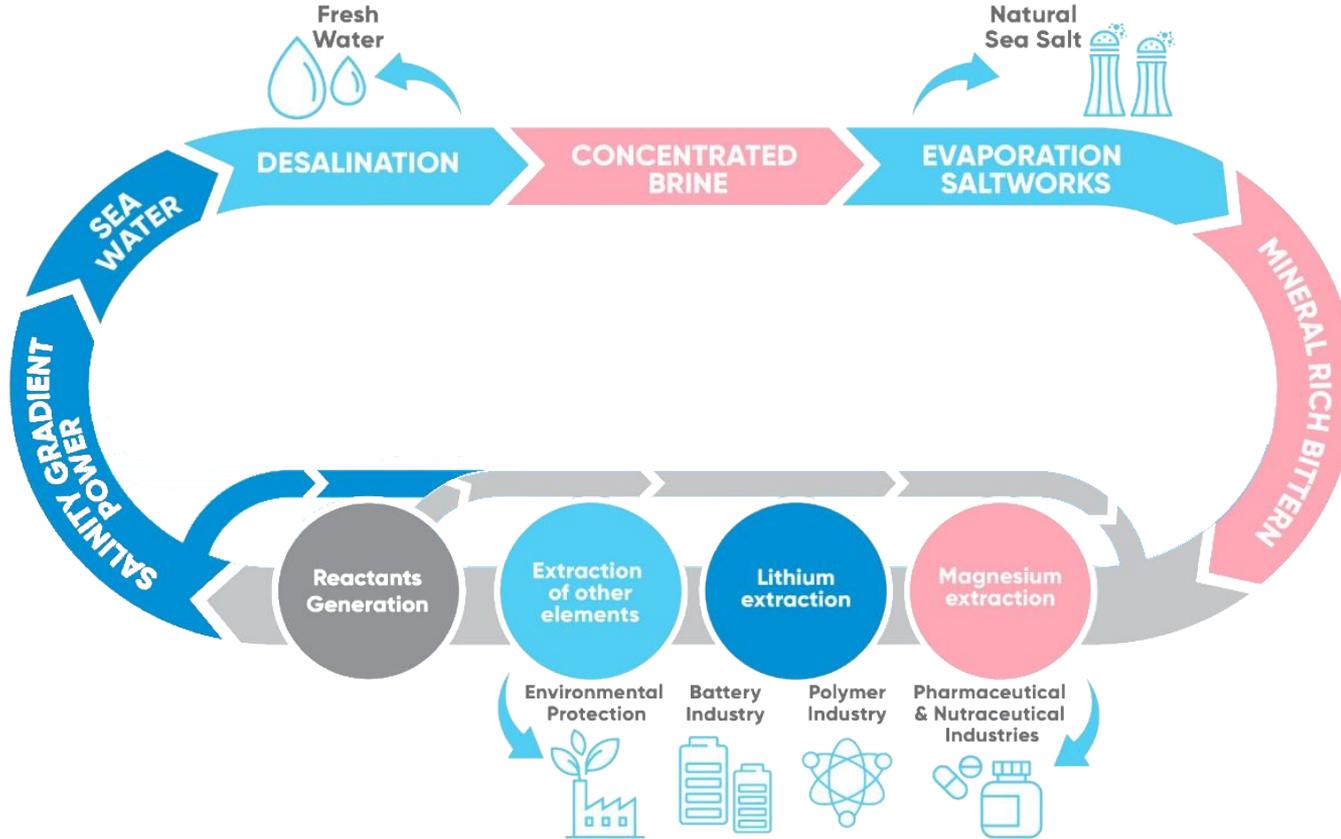
# Project Overview



From the original seawater circular mining concept to the integrated pilot plant



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From the original seawater circular mining concept to the integrated pilot plant

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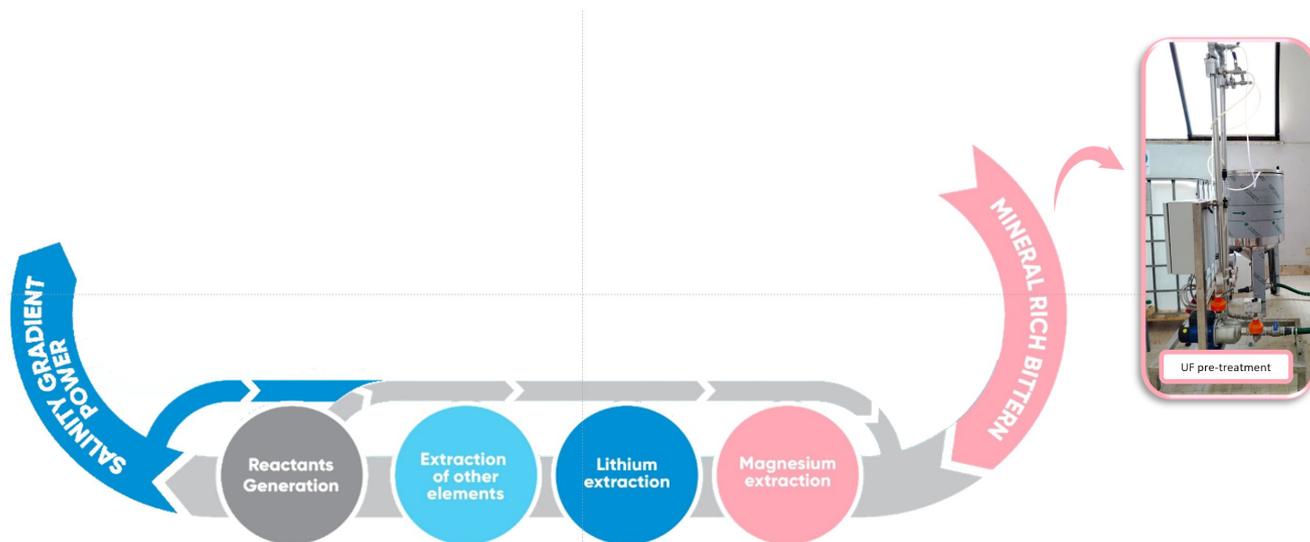


From the original seawater circular mining concept to the integrated pilot plant

  
IT Patent granted  
EU Patent pending

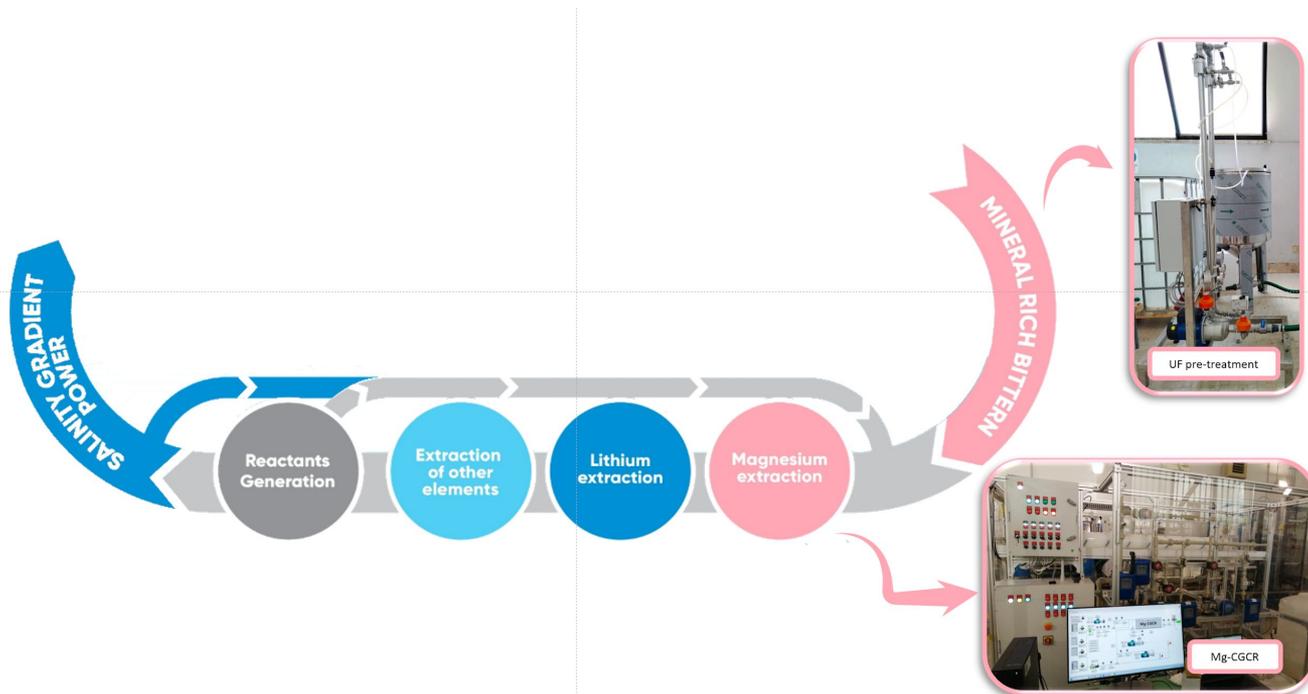
Circular Processing of Seawater Brines from Saltworks for Recovery of Valuable Raw Materials

# Project Overview

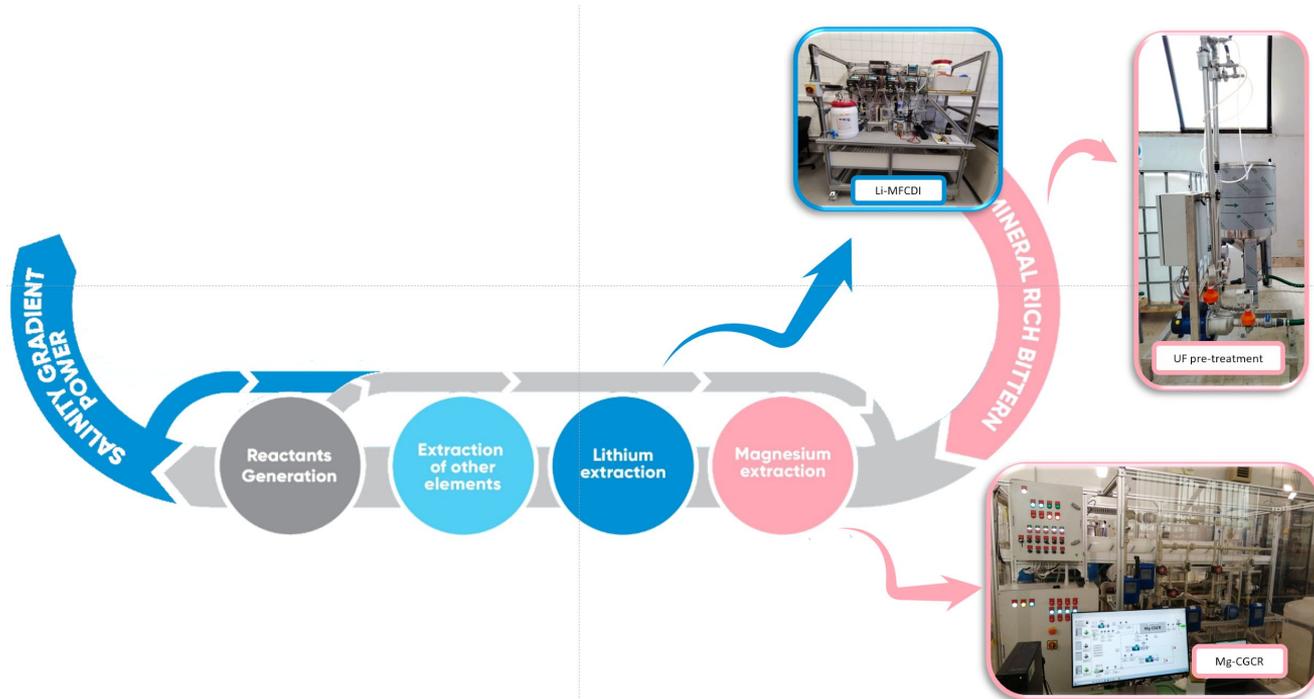


SEArcularMINE

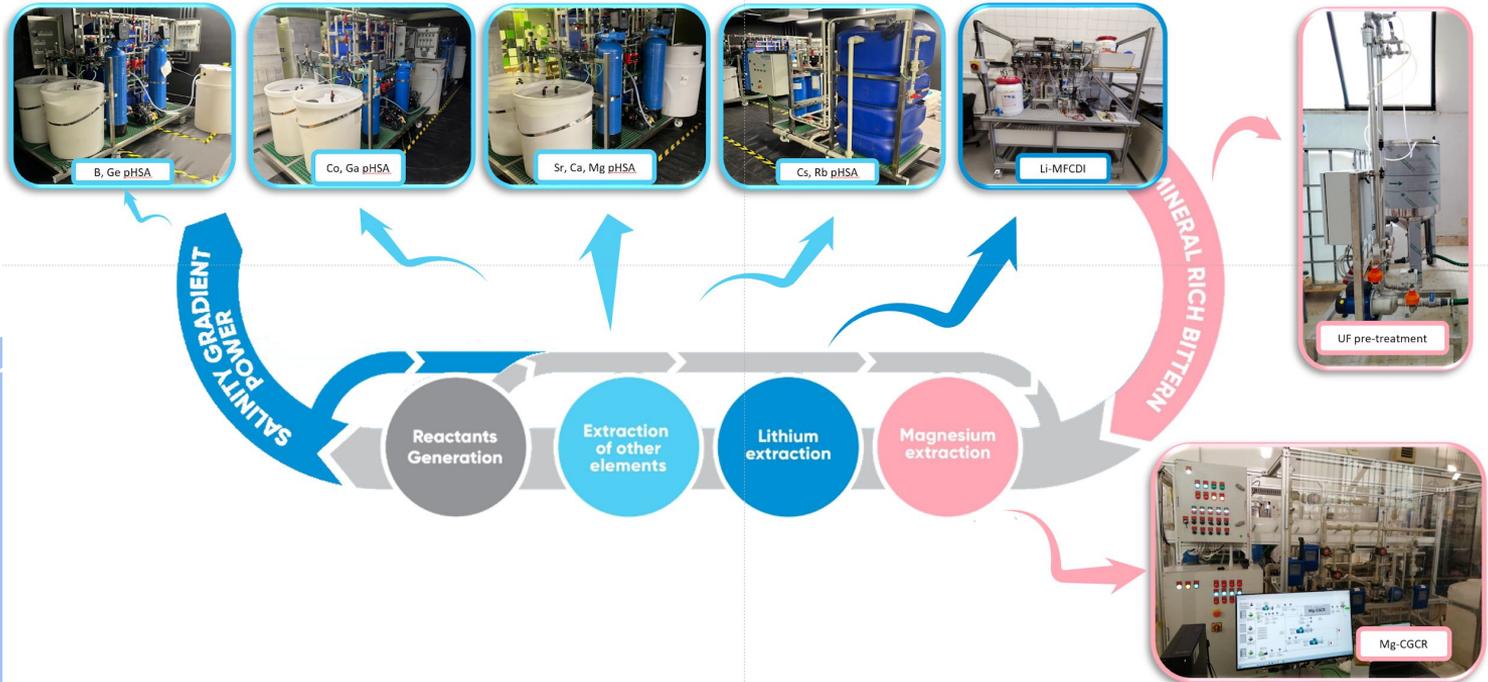
# Project Overview



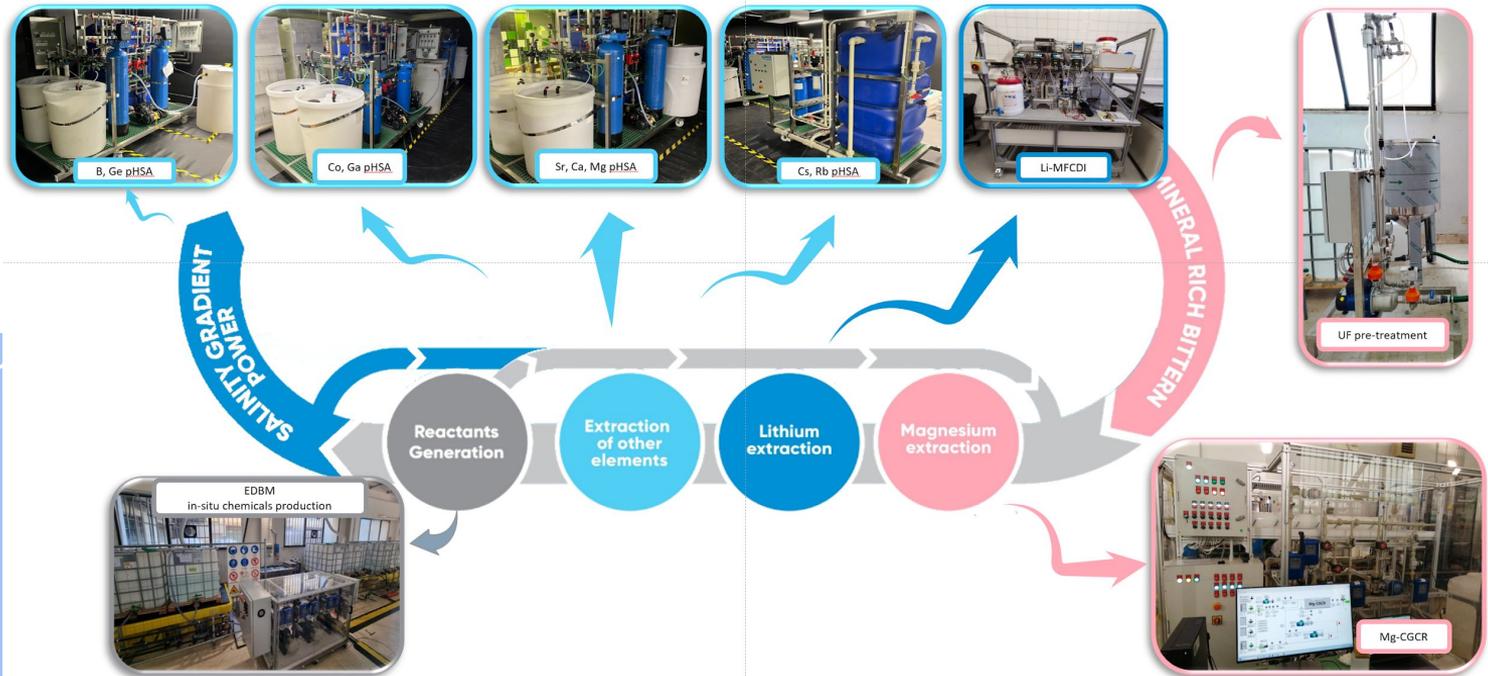
# Project Overview



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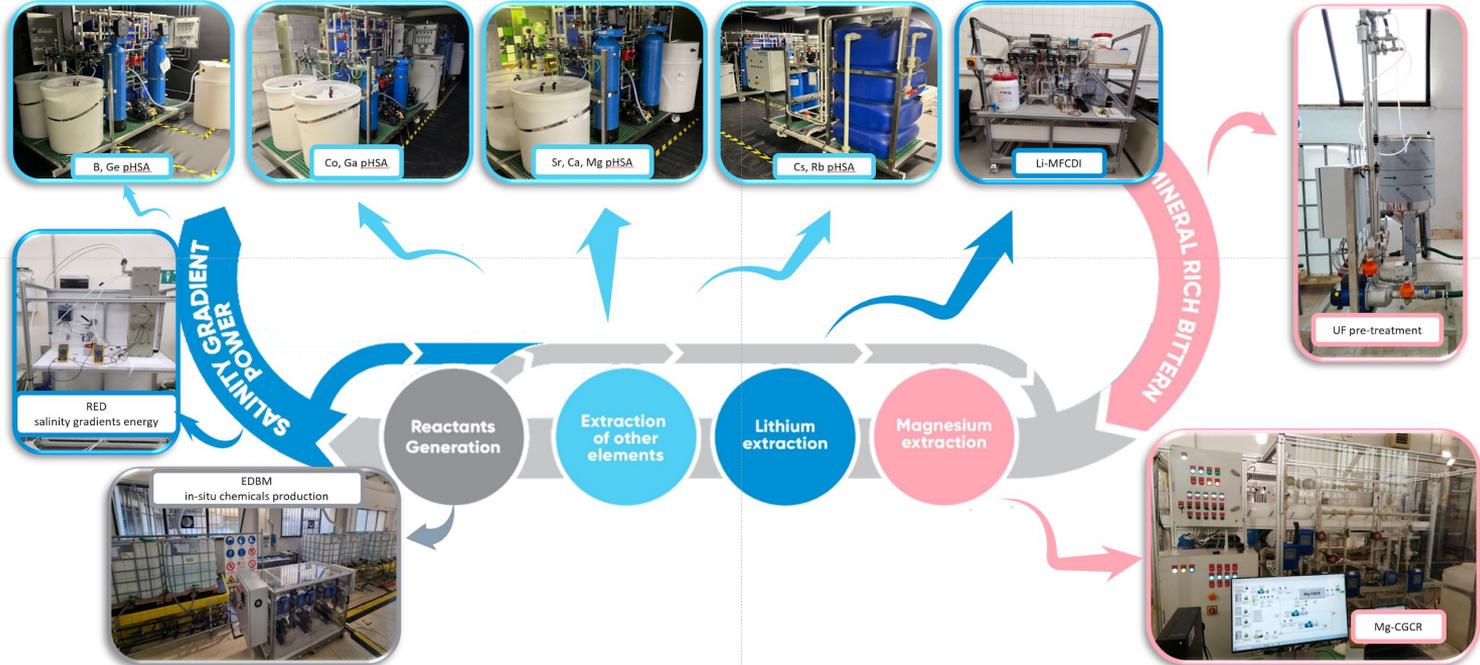


# Project Overview



SEArctular

# Project Overview

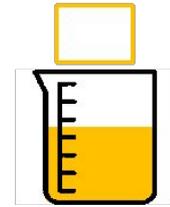
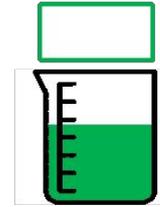
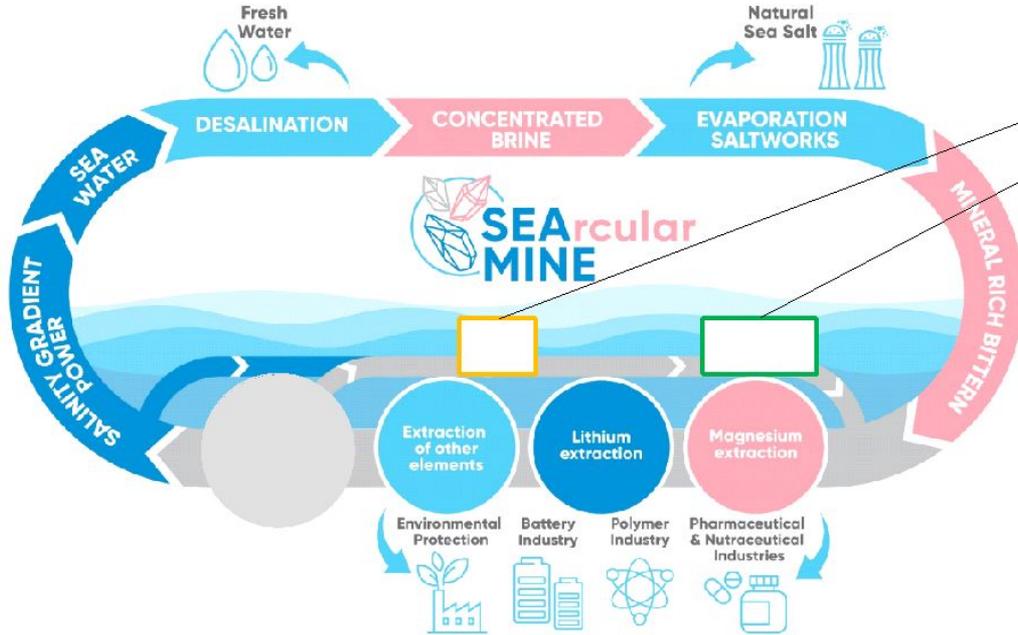


# Installation site

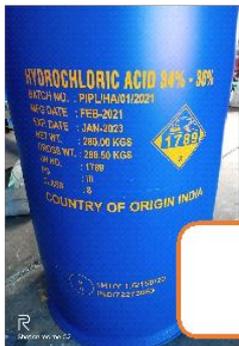
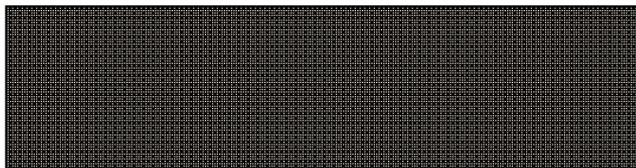
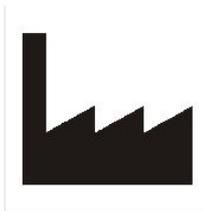


SEArclarMINE

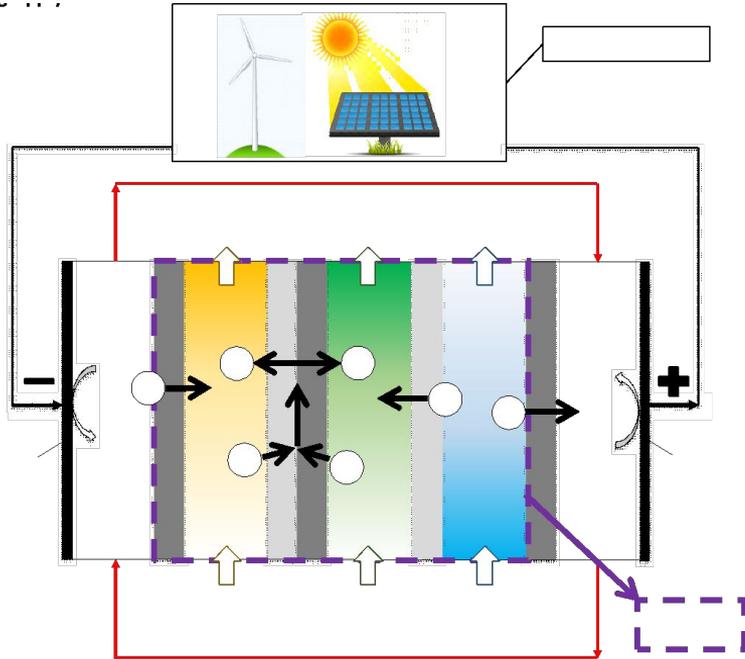
# Treatment chain



# Industrial Acid and Base production



# EDBM unit



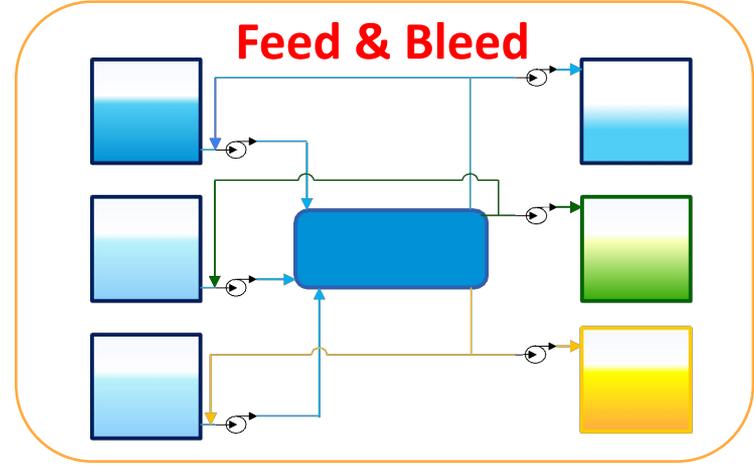
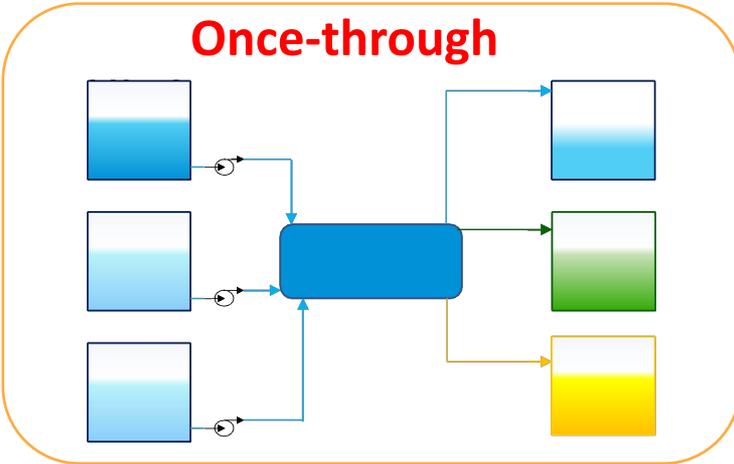
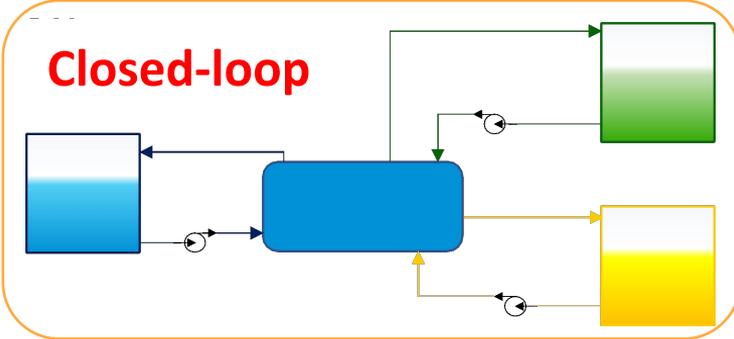
- **Concurrent production of NaOH and HCl**
- **In-situ reactants production from waste solutions**
- **HCl and NaOH can be recirculated into other process units promoting circularity**
- **Minimize CO<sub>2</sub> emissions**



- **High specific energy consumption**
- **High water consumption**
- **Elevate membrane cost**



# Operating configurations

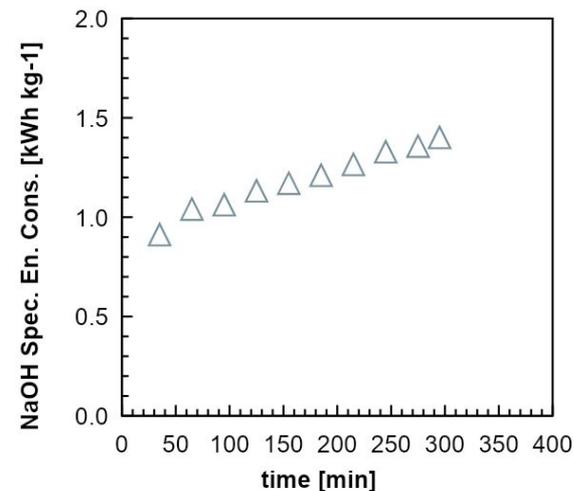
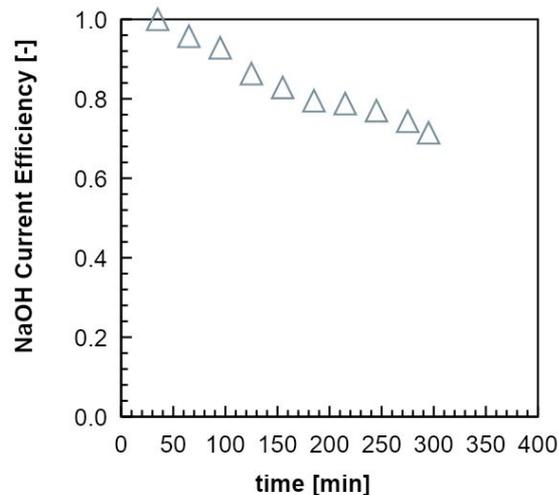
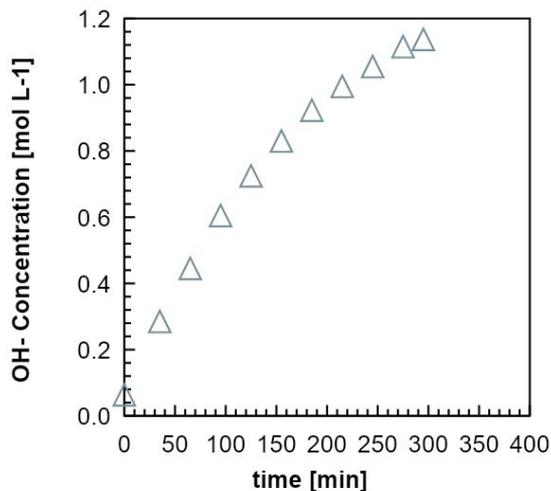


# EDBM Performance



Closed-loop (batch) configuration results  
Pilot-scale

$\Delta V_b = 250 \text{ L}, V_a = 500 \text{ L}, V_s = 500 \text{ L}$   
Applied voltage below 75 V or current  
density below 200 A/m<sup>2</sup>



Better performance are obtained in terms of higher Current Efficiency and lower SEC when EDBM operate at low concentration.

# Scale up of the process



Low-scale

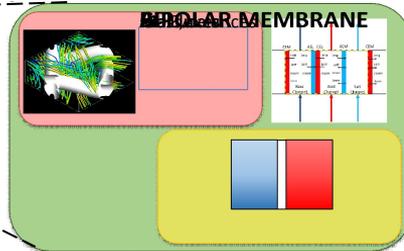
High-scale

*Lab experiments*

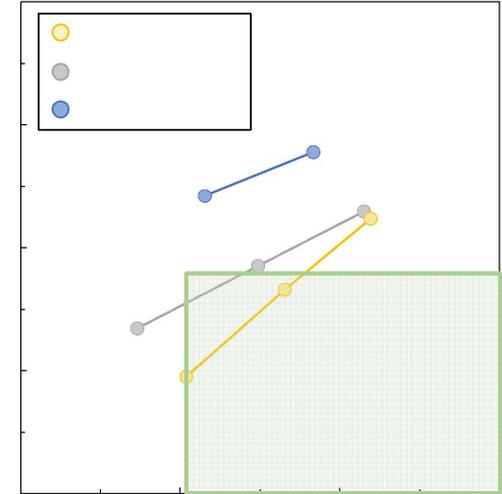
*Pilot plant development*



*Modelling*



Specific Energy Consumption, SEC [kWh kg<sup>-1</sup> NaOH]



**Specific Energy Consumption ~0.9 kWh kg<sup>-1</sup> NaOH**  
**Specific Productivity > 500 kg m<sup>-2</sup> y<sup>-1</sup> NaOH**

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# Example 2

# The Water Mining project



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 869474.

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# The Water Mining Project



It is a **research** and **innovation** project that develops **energy-efficient technologies** for treating **alternative WATER resources**, whilst promoting the **extraction (MINING) of valuable products** from the residues generated during the process.



**6 Case Studies**



Desalination  
**Sea-mining**



Urban wastewater  
**Urban-mining**



Industrial used streams  
**Industrial-mining**

# The Water Mining Project



## The concept behind the project: Water Value Chain

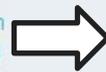
1

### Water as a Resource

Water demands must be met by policymakers, and in the face of increasing water scarcity, alternative water resources must be integrated into the supply. Desalination is expected to play a key role, especially in water-stressed regions.



Desalination  
Sea-mining



Case study 1

2

### Water as a Consumable

Over the last century the global population tripled, and together with increasing levels of consumption and living standards, water demand increased substantially. Urban water consumption is an important fraction of the total human water use, but it presents a possible alternative source of water via wastewater recovery technology.



Urban wastewater  
Urban-mining

3

### Water as a Durable

Durable goods are defined as goods used for final consumption regularly over a period of over one year. Development of innovative technologies to reuse industrial water is promising for reducing water demand from within this sector via advanced wastewater treatment and recovery technology.



Industrial used streams  
Industrial-mining

Data-mining

### New water services

- Fit-for-purpose water
- Carbon neutral water services
- Safe water reuse
- Smart water management
- Recovery and supply of critical raw materials
- Supply of nutrients
- Supply of alginate-like polymers
- Rate setting mechanisms
- Demand management

# Seawater treatment chain

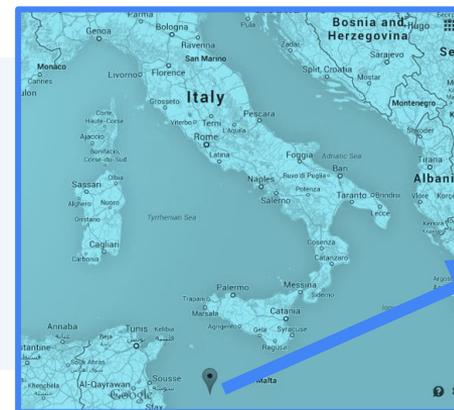


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## Case Study 1 in Lampedusa, Italy

Lampedusa, a small Sicilian island affected by fresh water scarcity, presents a **SWRO** plant with an installed capacity of around **3,500 m<sup>3</sup>/day** which:

- Covers **100%** of the total drinking water needs of the island;
- Consuming **10%** of the energy generated by the Power Station of the island.



## Lampedusa



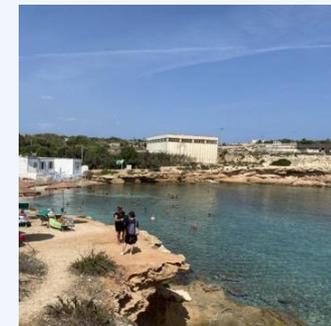
## Main objectives of Case Study

- Prove the advantages of advanced desalination combined with **waste heat recovery** (from the Diesel engines)
- Contribute to **energy saving** through softening pre-treatment
- **Desalinate** water and produce **high quality salts** (such as NaCl, Mg(OH)<sub>2</sub>) and **chemicals** (such as HCl, NaOH)



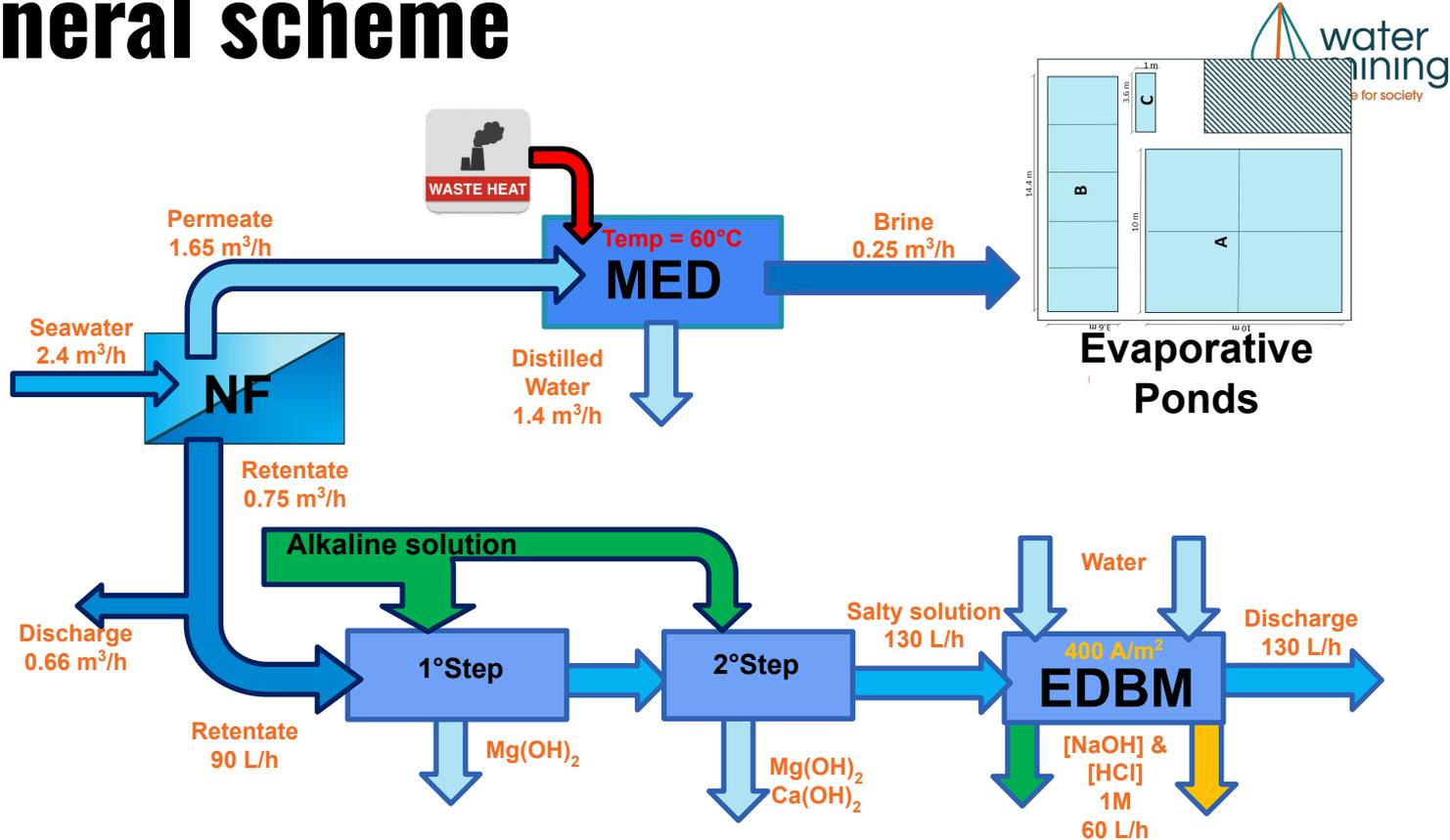
## Installation and Demonstration of a seawater treatment chain

at Cala Pisana, Lampedusa  
(Site of SWRO plant and Power station)

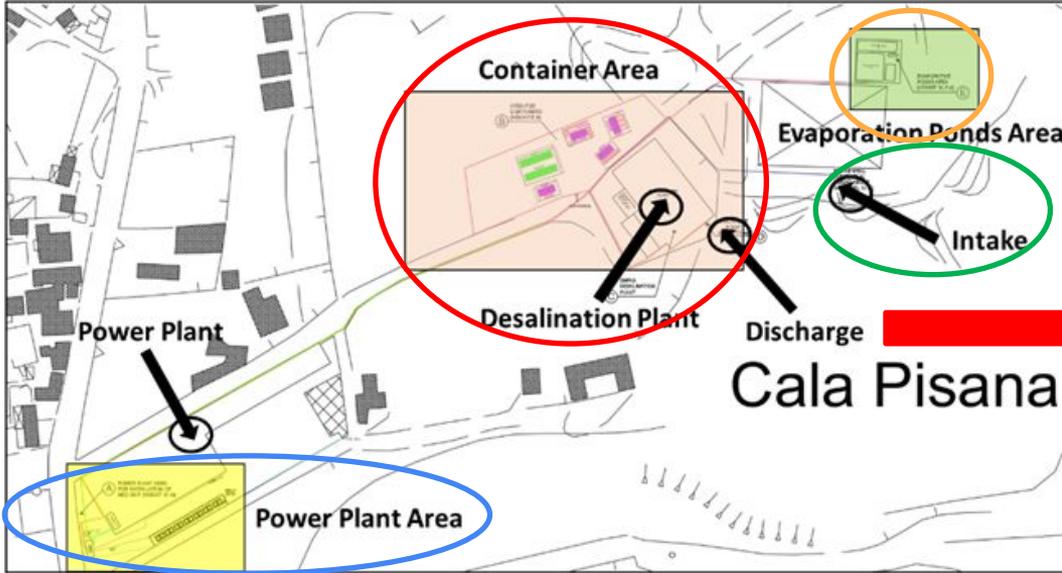


**Cala Pisana, Lampedusa**

# General scheme



# Layout of pilot plants



Ponds Area



Containers



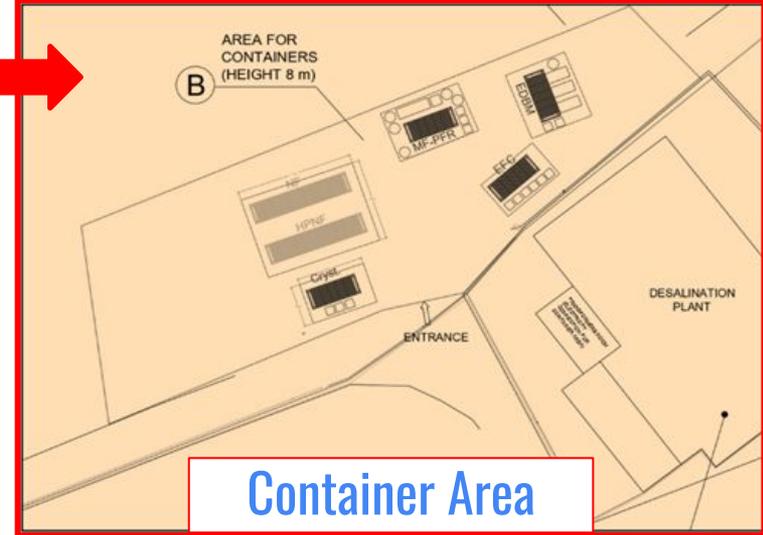
Power Plant



Intake



Cala Pisana



Container Area

# Key Achievements



A treatment chain for **brine valorization** has been installed at Lampedusa (Sicily, Italy)

The **pilot units** includes:

- (i) Nano Filtration (NF)
- (ii) Multiple-Feed Plug Flow Reactor (MF-PFR)
- (iii) Electro-Dialysis with Bipolar Membrane (EDBM)
- (iv) Multi-Effect Distillation (MED)

**Results** of the experimental campaign showed that:

**NF:** High NF rejection was obtained for Mg (higher than 98%), Ca (higher than 95%) and Sulphate (higher than 99%) - Stability of NF during the Long Run test (about 77 Hours)

**MF-PFR :** High recovery was obtained for Mg, higher than 97% - High  $Mg(OH)_2$  purity was obtained, higher than 95% - High Ca/Mg removal efficiency was achieved, higher than 95% (for both cations) - Stability of MF-PFR during the Long Run test (about 60 Hours)

**EDBM** unit allows the production of **1M NaOH/HCl solutions** with average **SEC** of  $\sim 2 \text{ kWh kg}^{-1}_{NaOH}$  and high **current efficiency** (i.e., >69%)

**MED** unit allows low conductivity of distillate, below  $25 \mu\text{S/cm}$ , high conductivity of brine, higher than  $220 \text{ mS/cm}$ , concentration factor up to 8

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# Example 3

# The ReWaise project



This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 869496.

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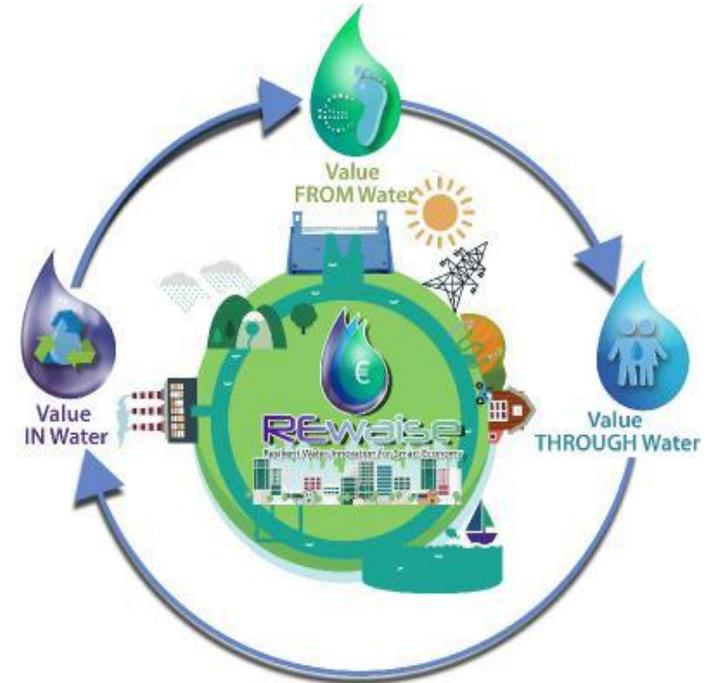
# The ReWaise Project



- Water scarcity, reduction of fresh water due to **pollution** and **climate change**
- Population growth and **increased demand for water**
- **Minerals** and **metals scarce in Europe**. Security in supply for economic independence
- The water sector is one of the largest consumers of energy, leaving a significant **carbon footprint**

## Project motivation

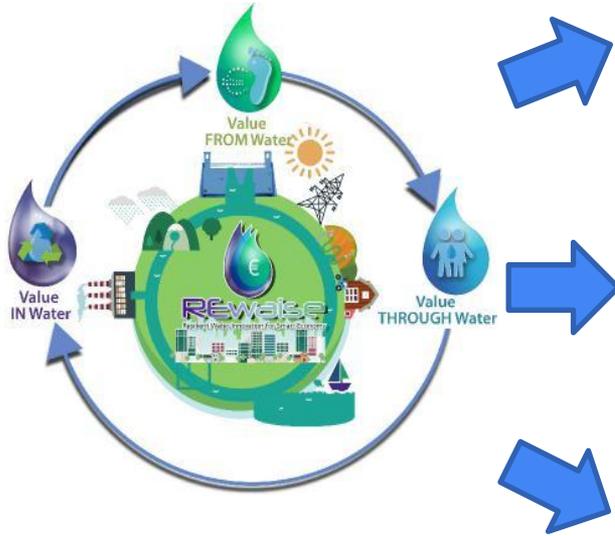
To solve these problems of **water scarcity** and **energy consumption**, REWAISE proposes to change the paradigm, towards a carbon-neutral water cycle, taking advantage of the value in water, from water and through water.



# The ReWaise Project



The REWaise Project demonstrates innovative **technologies**, **processes** and **governance models**



IN

Recovering **materials** and energy, to maximize business innovation



FROM

Creating **new economic activities**, jobs and the application of social innovation

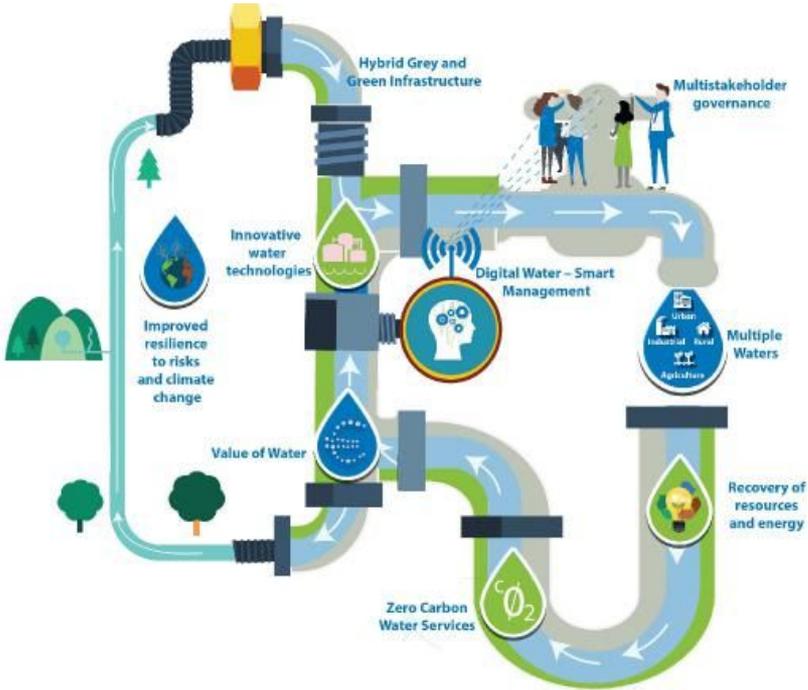


THROUGH

Sharing the value through water, **generating benefits** for the environment and the well-being of a smart water society



# ReWaise concept

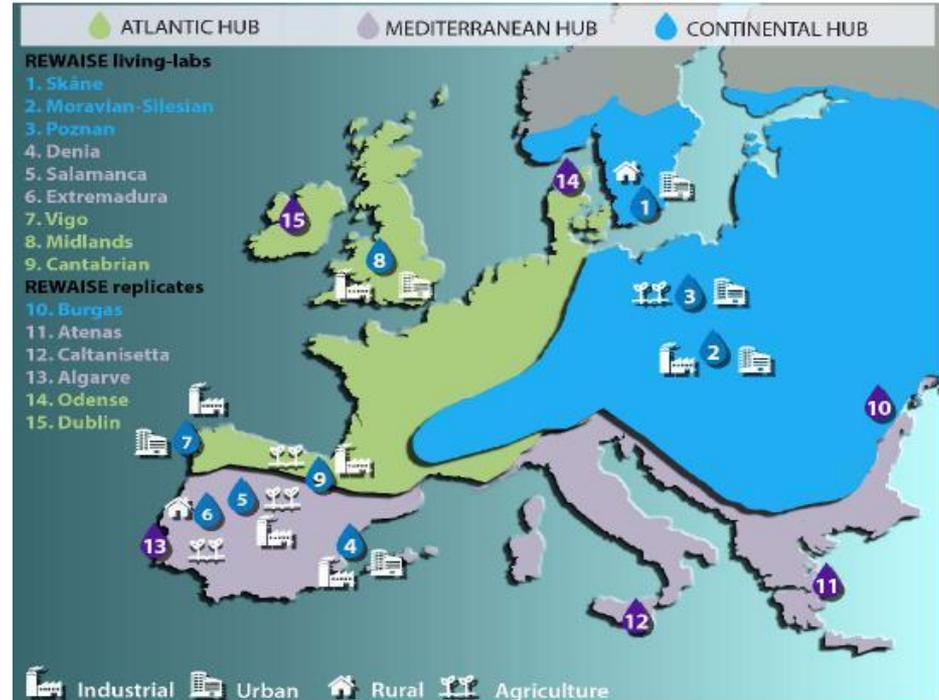


- Innovative technologies
- Involvement of stakeholders
- Suitably developed digital monitoring system
- Suitably designed management applications

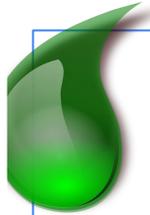
# Demonstration sites



**9 “Living Labs”** to DEMONSTRATE innovative **technologies** and **operational strategies**, enhance **social engagement** and develop **digital tools** in a holistic **smart society** approach to Water



# Hubs



## Atlantic hub

Proper management of the water infrastructure, both in terms of new management strategies and new ways of **wastewater valorization**



## Mediterranean hub

Water scarcity is going to be addressed with the use of novel **desalination technologies**



## Continental hub

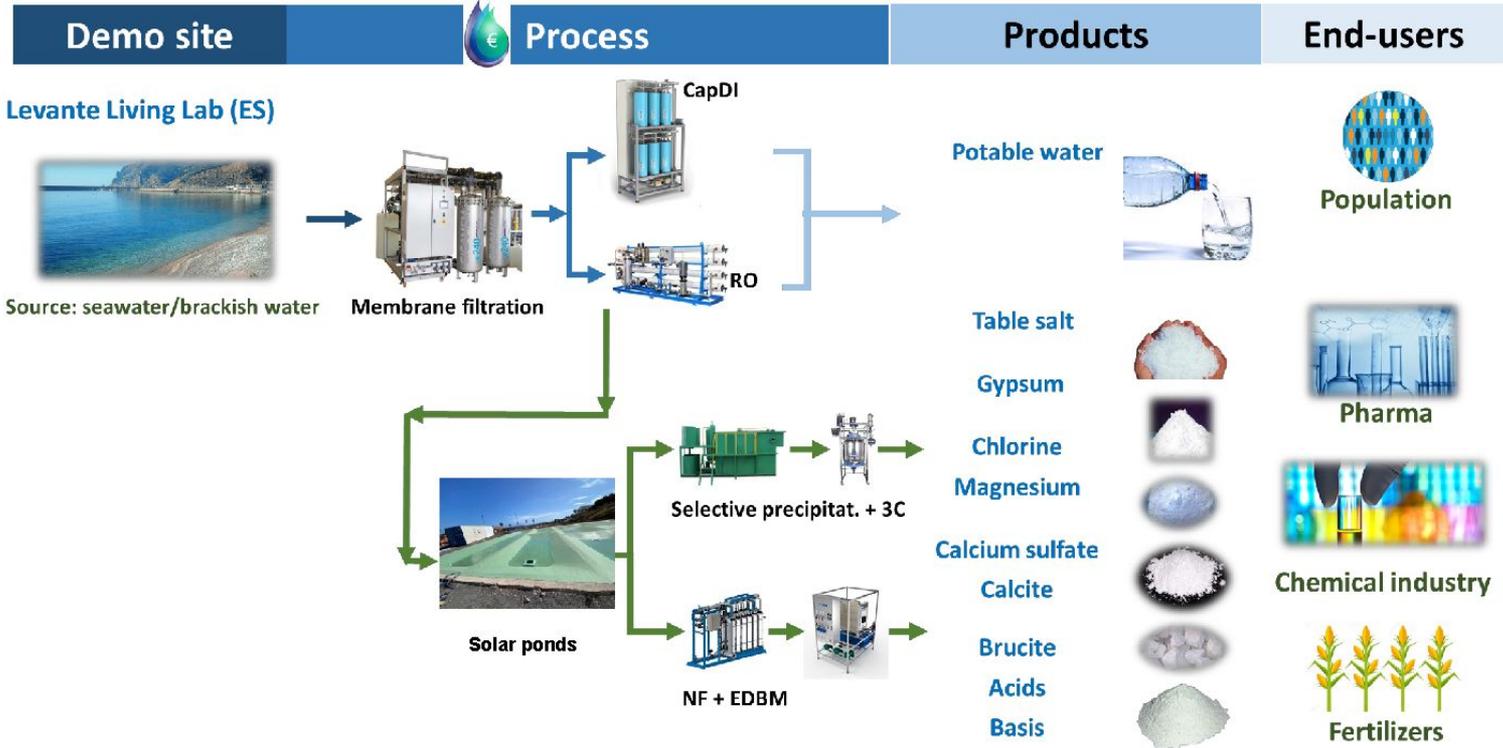
Alternative water sources for agriculture will be sought in rainfall and storm harvesting. Also **brines** from mines will be valorized

# Process description



A **minimum liquid discharge (MLD)** desalination for water recovery maximization and resources reclamation

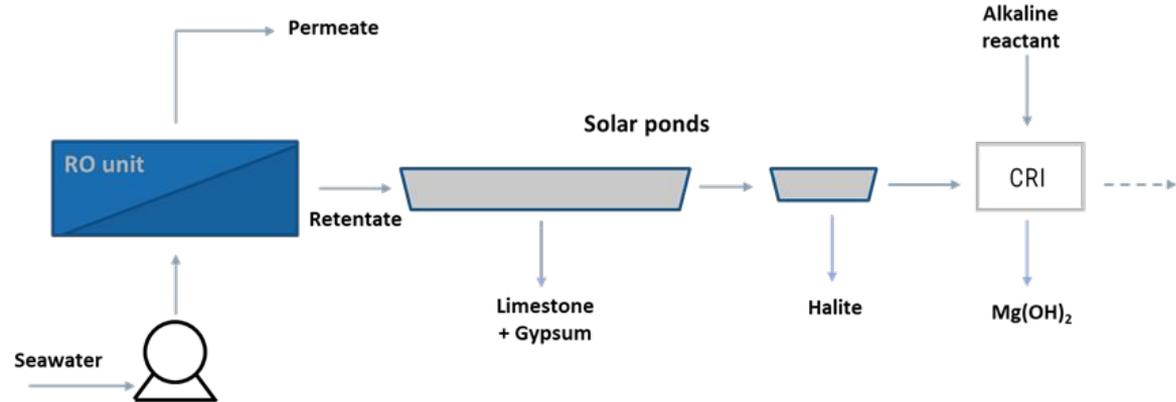
Mediterranean



# Low energy desalination and mineral recovery

The aim of the activities is the **recovery** of **valuable materials** via:

- Saltponds
- Magnesium crystallizer



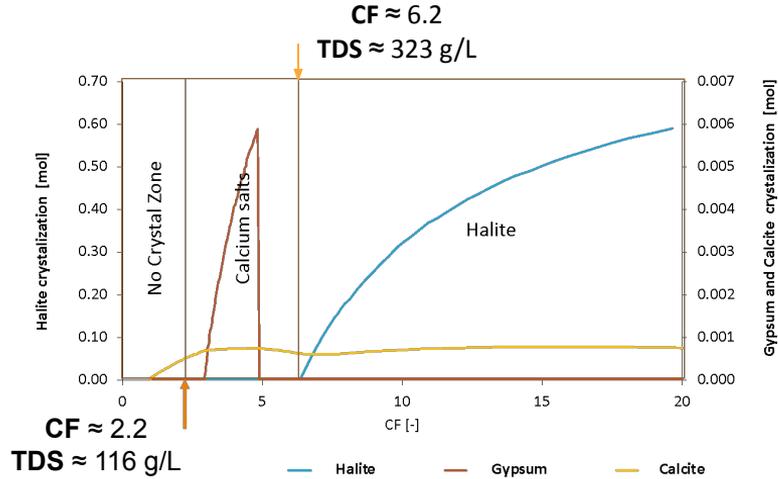
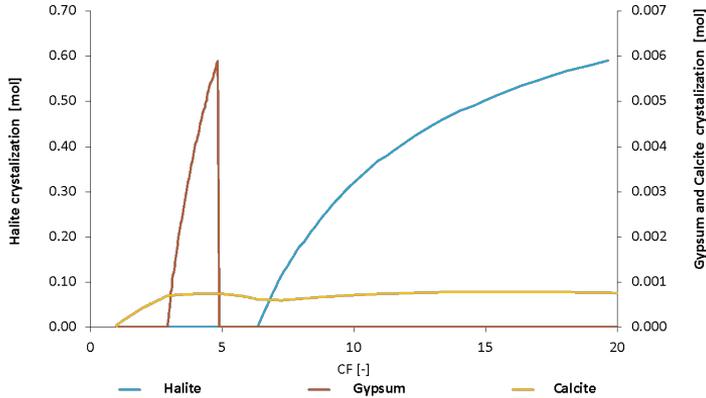
Mediterranean  
Hub



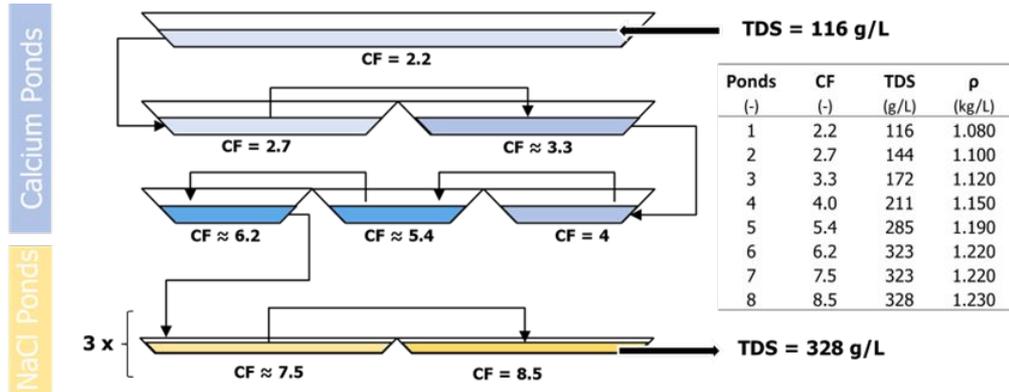
# Design of the evaporative ponds



## Modelling



## Schematization



# Evaporative ponds

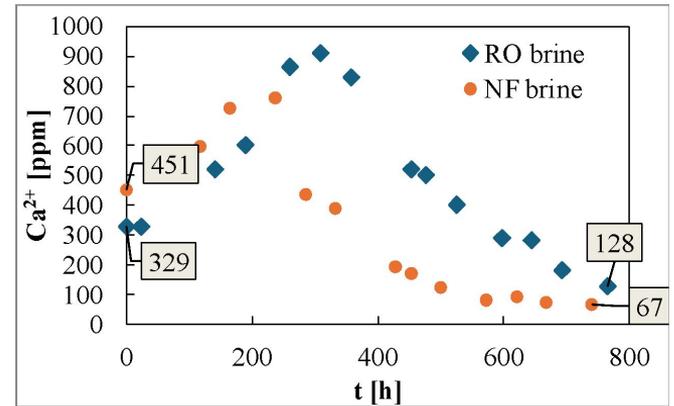
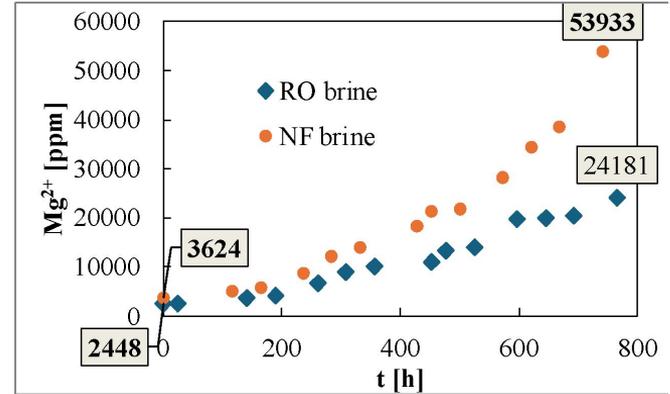
## Operation



Mediterranean Hub

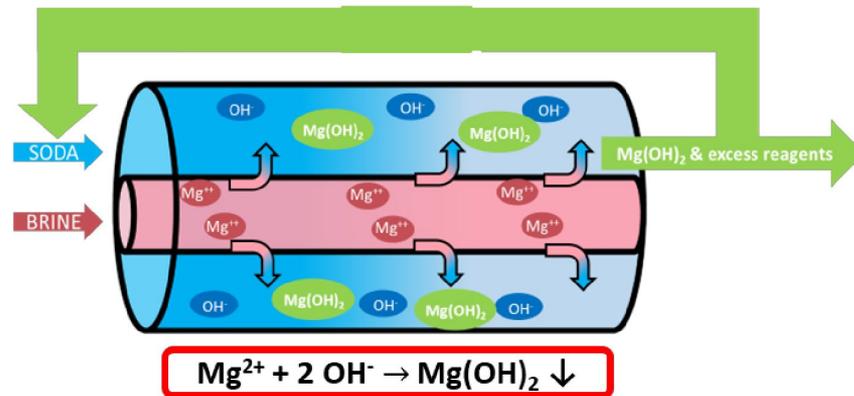
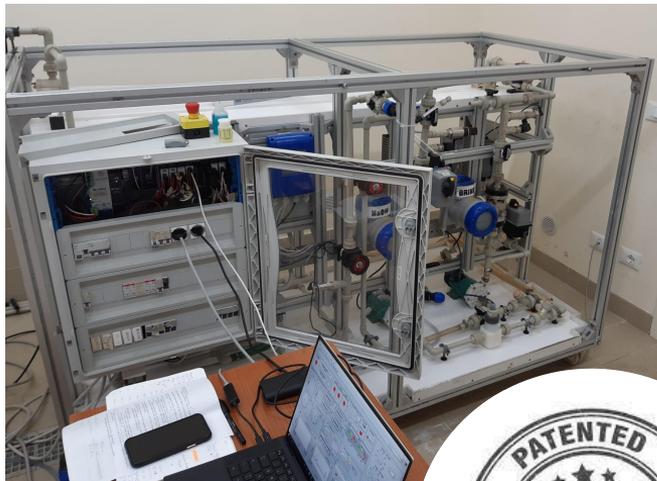


## Results

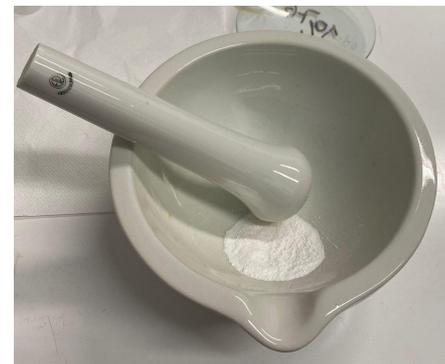


# Magnesium reactor

## Crystallization reactor design and construction



Mediterranean Hub



Magnesium Hydroxide

# Ongoing activities



Adeje



Installation Site

Magnesium reactor under operation



Evaporative Ponds Bittern and Salts production

Mediterranean Hub