KERC KOREA-EU Forum

KICT KOREA INSTITUTE of CIVIL ENGINEERING and BUILDING TECHNOLOGY

Water-Energy-Resource Nexus

Oct. 16. 2025.

June-Seok Choi

Introduction

June-Seok Choi

Education
- B.E. Korea Univ.
- M.E. Korea Univ.
- Ph.D. Korea Univ.

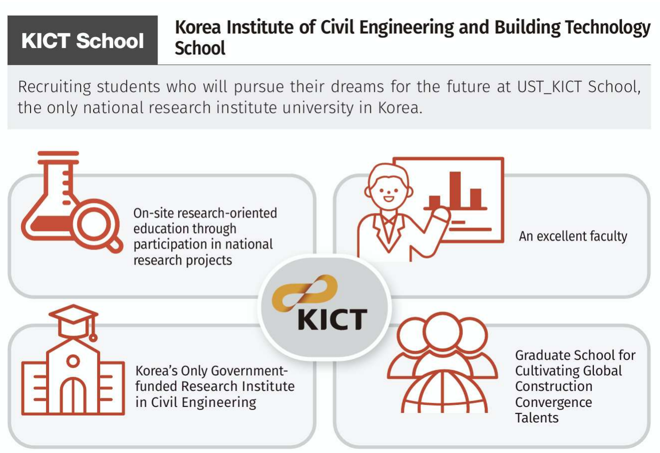
Experiences
- Research Fellow
- Representative Professor
- Vice President, Korean Society on Water Environment
- Editorial Board Member, Desalination
- Visiting Researcher, EURECAT(Spain), MSCA

Research Field
- Water & Wastewater Treatment, Desalination, Water reuse
- Resource recovery

KICT (Goyang, Gyeonggi do)

Korea's only comprehensive construction research infrastructure

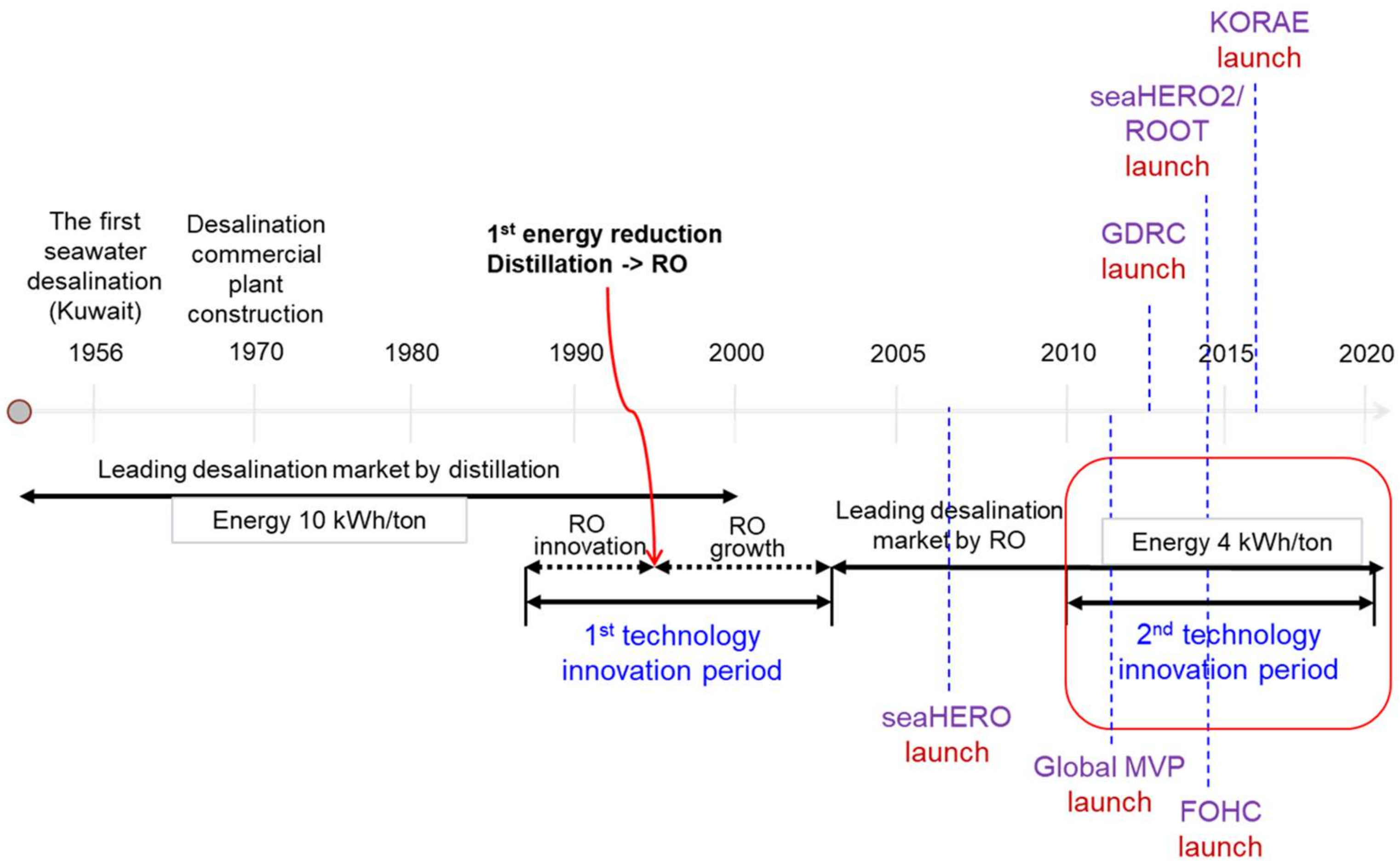
Key facilities: Future Convergence Building, Large Structure Experiment Building, Port Experiment Building, Integrated SOC Management Center



Experiences

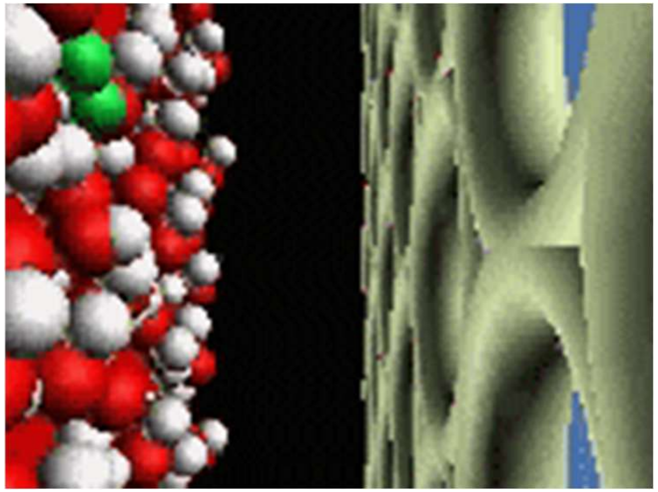
Introduction

Development of Desalination Technology



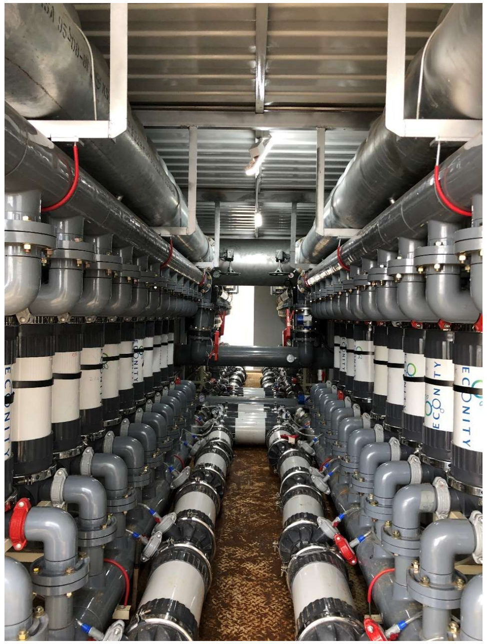
Case 1: GMVP (MD)

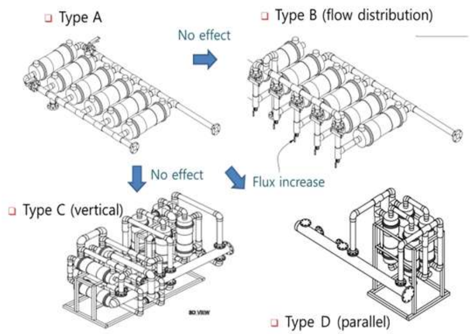
❯ Membrane Distillation (MD)



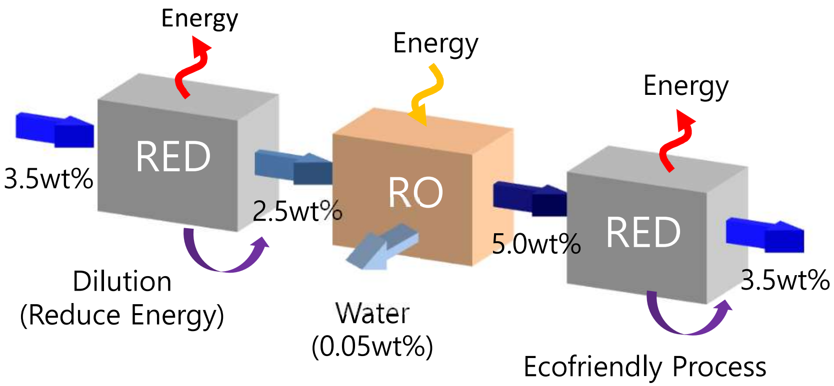
- Thermally-driven membrane process
- Capable to treat highly saline feed water
- Capable to use low-grade thermal energy such as waste heat, solar, or geothermal energy

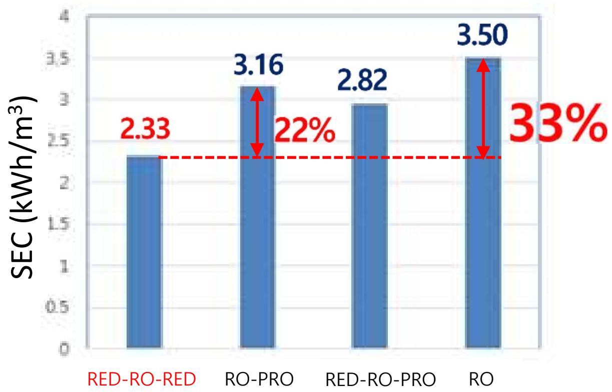
GMVP (400 m^3/d)





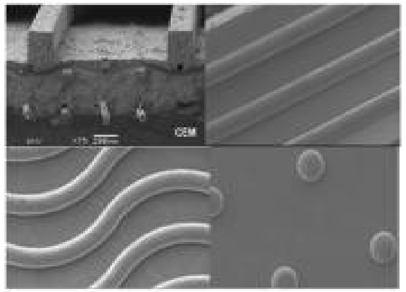
Case 2: RED-RO Project (100 m^3/d)





RED

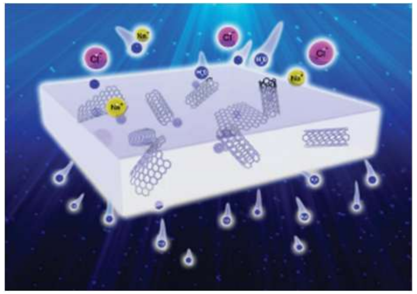
Ion-exchange membrane



- Energy Density 2.2 W/m²
  Vs. 0.6~0.8 W/m² Fujifilm

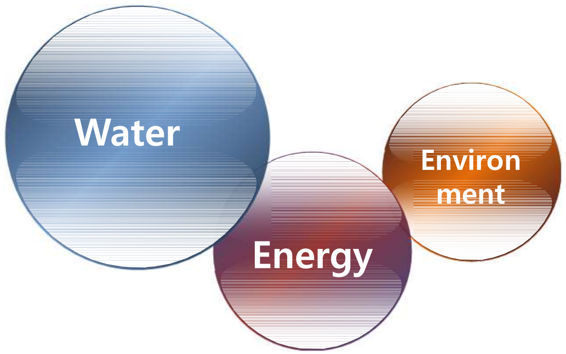
RO

New Membrane



- New membrane for 2-2.5wt%
  (Salt Rejection>99.9%, Flux>2.0 LMH/bar)

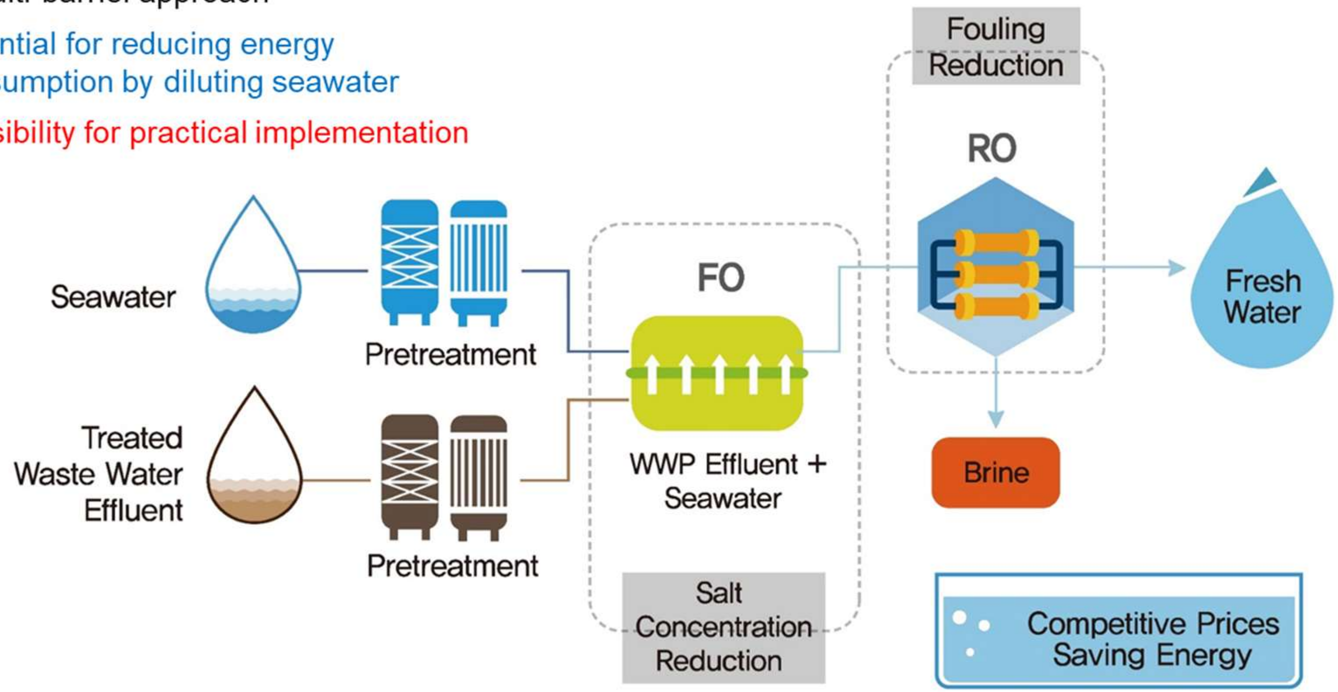
Next Generation Desalination



Case 3: FOHC Project (FO-RO)

Key Concept for FO-RO Hybrid System
Integration of desalination and water reuse
Low Energy Consumption and Fouling Reduction

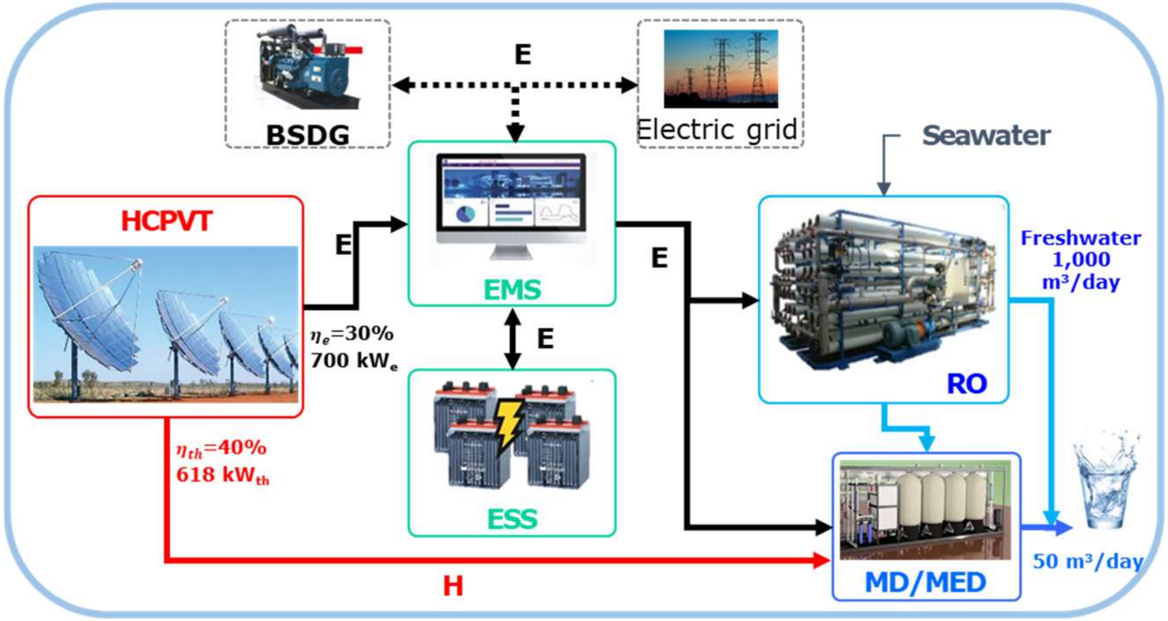
- FO without draw solute recovery
- Osmotic dilution
- A multi-barrier approach
- Potential for reducing energy consumption by diluting seawater
- Possibility for practical implementation



Case 4: Renewable energy + Desalination

Concept of HCPVT + RO + MD System

= HCPVT(High Concentration Photo-Voltaic Thermal) + ESS(Energy Storage System)
+ EMS(Energy Management System) + BSDG(Black Start Diesel Generator)
+ RO(Reverse Osmosis) + MD(Membrane Distillation)/MED(Multi-Effect Distillation)

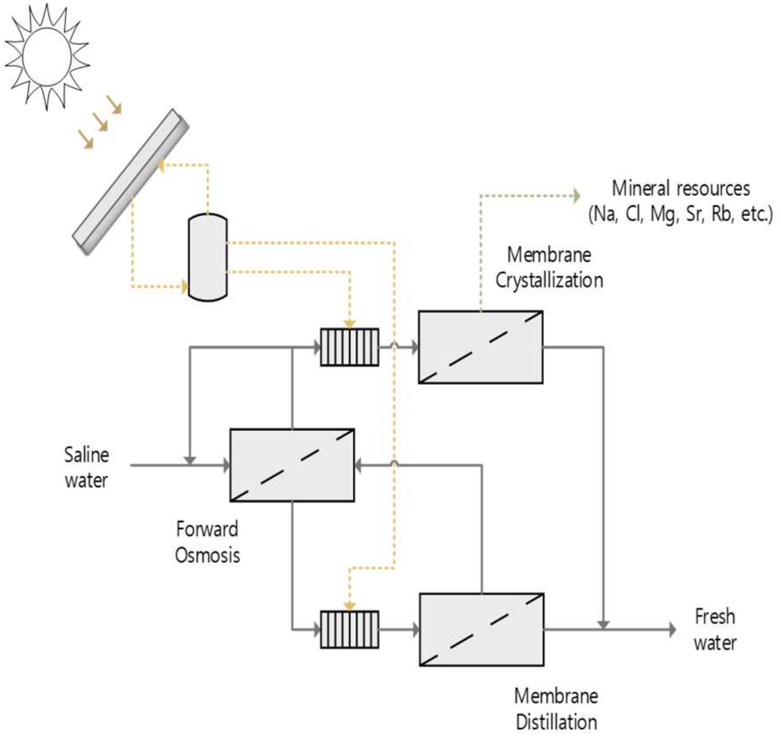


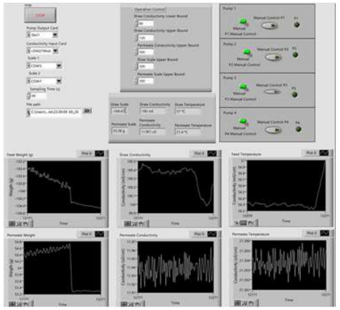
- HCPVT-RO-MD hybrid system ≤**3.3kWh/m³, 1000 m³/day**
- HCPVT Energy eff.≥70%, (Electricity≥30%, Thermal≥40%)
- Compare to PV-RO
  - CAPEX is similar
  - Footprint : 24~59% ↓
  - Productivity : 5~10% ↑

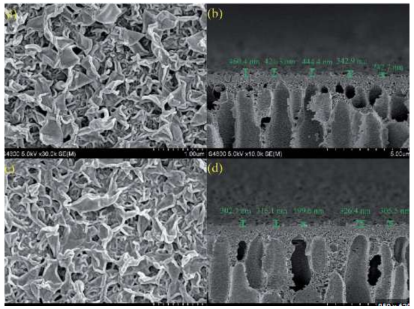
Case 5: TECNIOSPRING in Spain (MSCA)

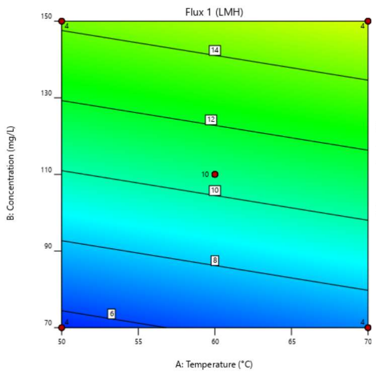
› Prototype of Technology

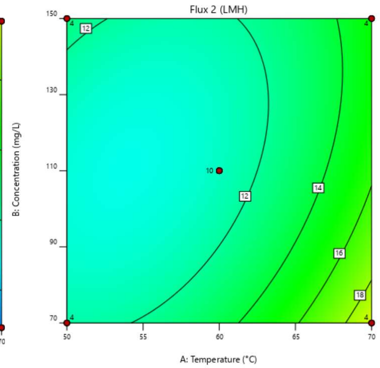
Topic: Development of solar thermal hybrid (FO-MD-MCr) system

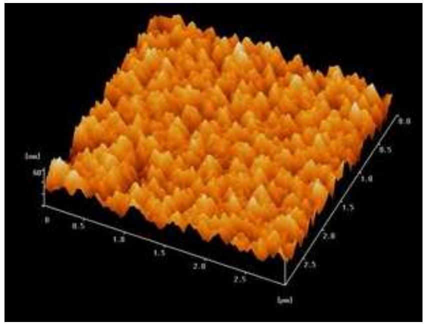






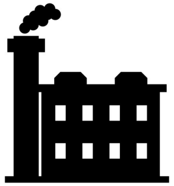


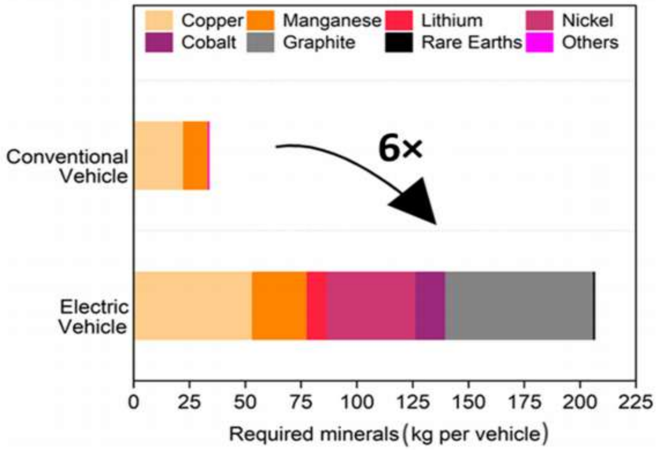




Resource

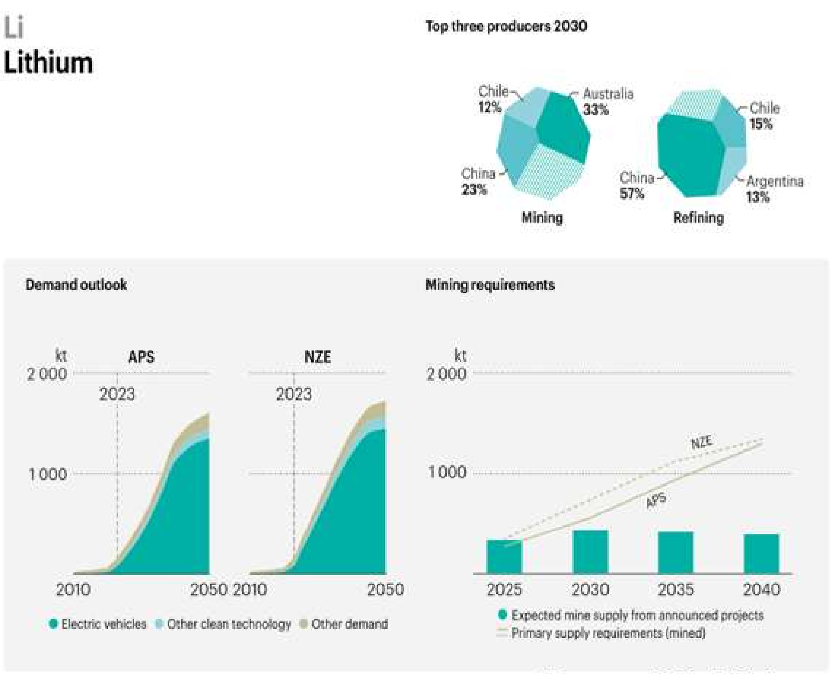
Resource





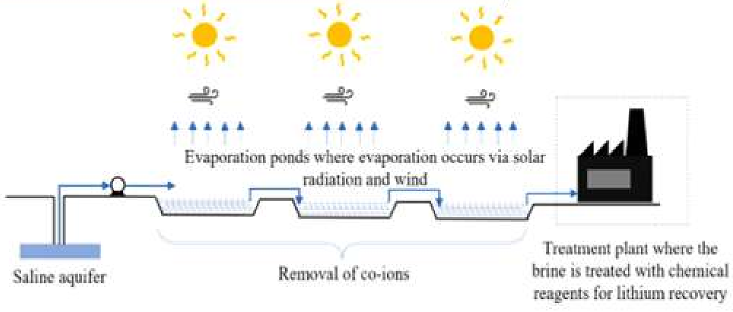
Source: https://doi.org/10.3390/batteries10010038

Lithium



*Source: IEA, 2024

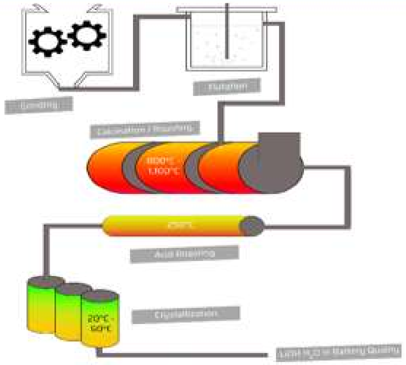
Evaporation Pond



*Source: Lenntech, 2024

- ✓ Time Consuming

Hard Rock Extraction

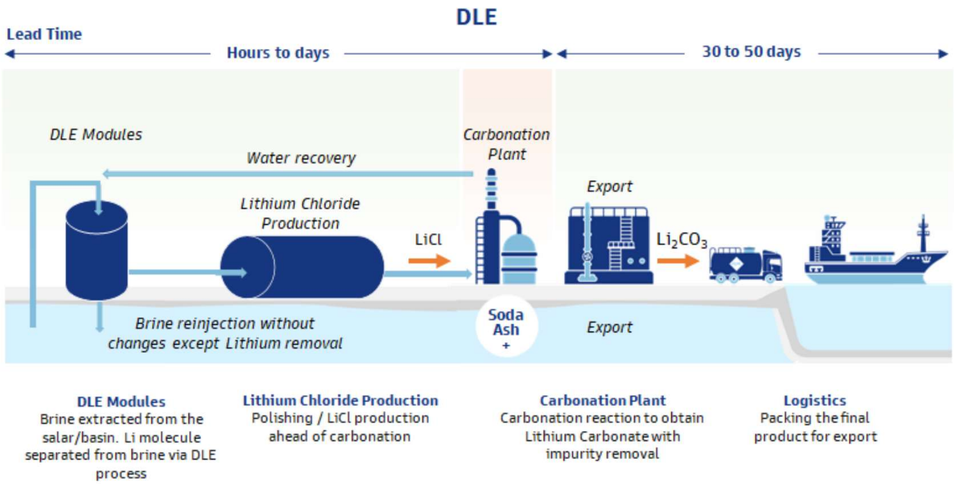


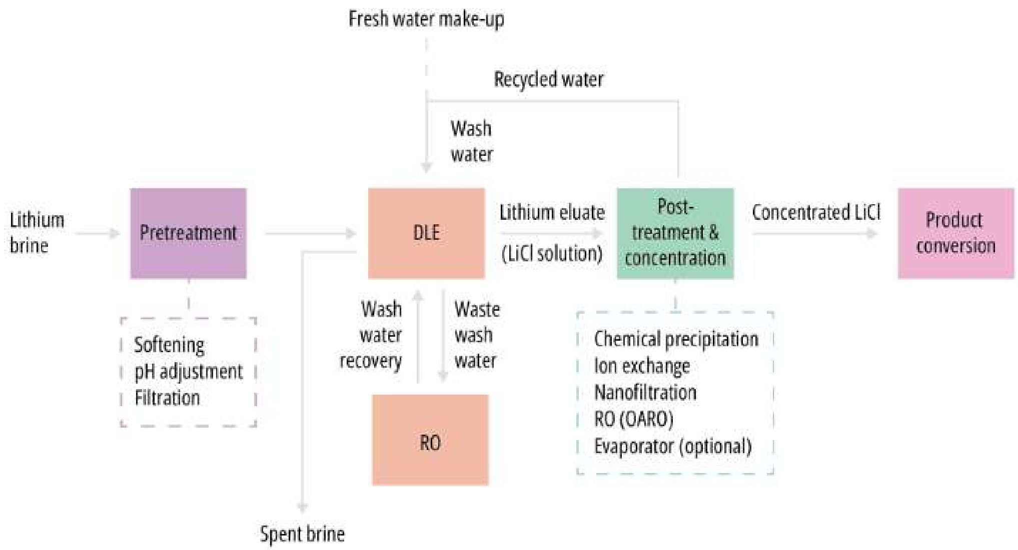
*Source: KraftBlock, 2024

- ✓ High Water consumption
- ✓ High Carbon Footprint

Lithium recovery

- **Direct Lithium Extraction (DLE)**
- **Game Changer**

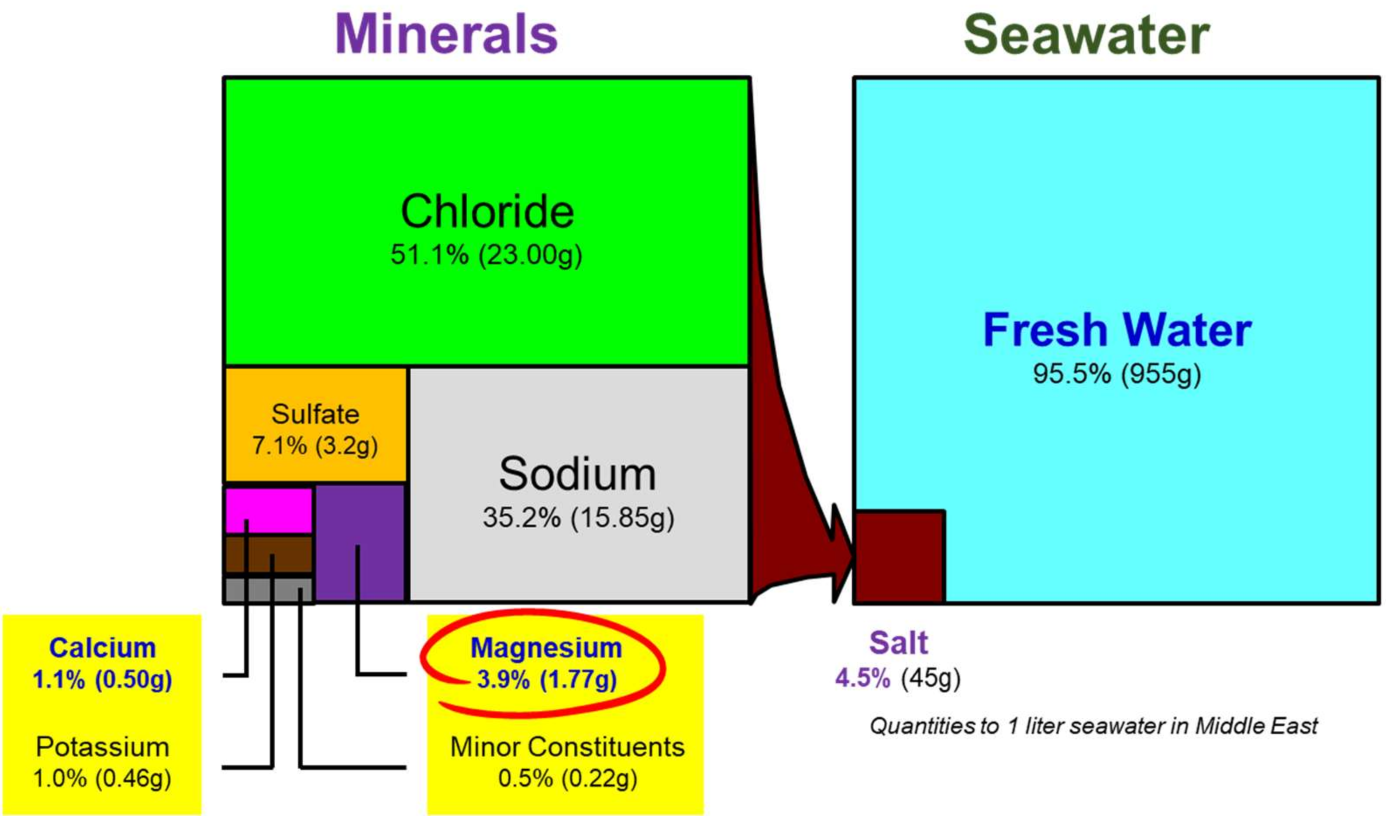




Source: GWI adapted from Saltworks, Goldman Sachs and International Lithium Association

Brine

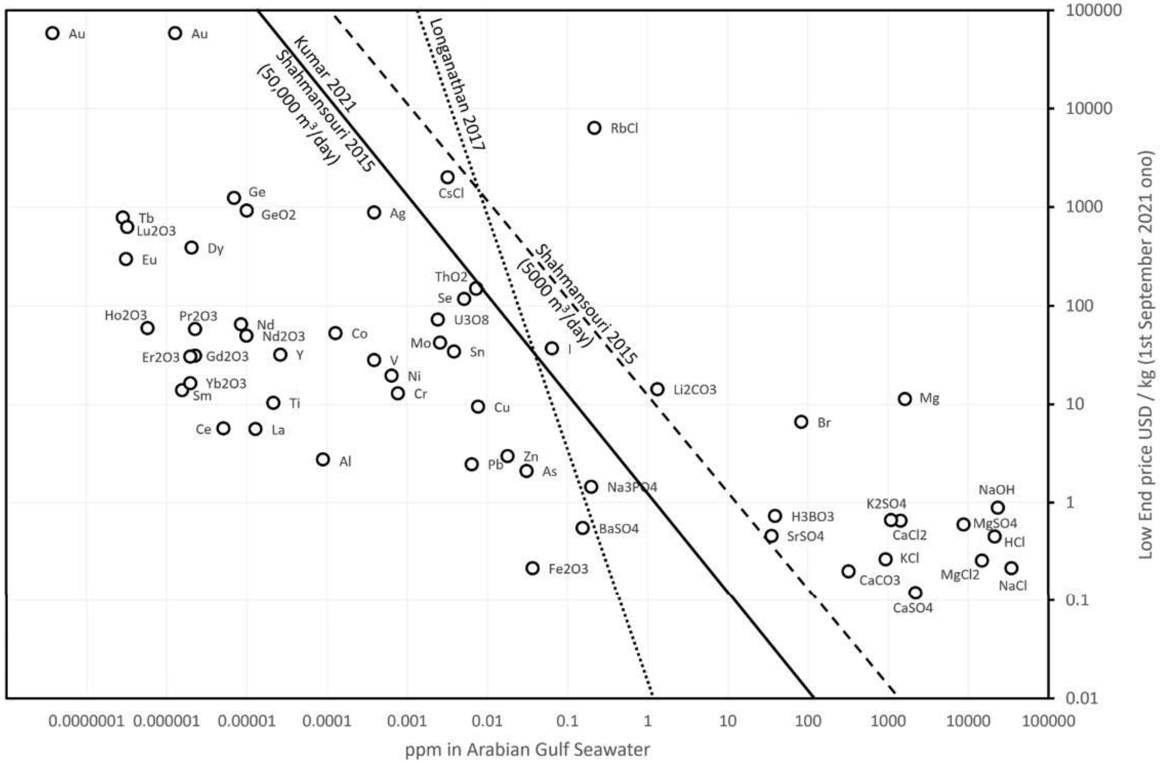
Seawater could be a valuable resource!



Brine

Fig. 1: Element concentration and price.

From: Seawater desalination concentrate—a new frontier for sustainable mining of valuable minerals



https://doi.org/10.1038/s41545-022-00153-6

Recycling Technology in Battery Industry

- **Pyrometallurgy & Hydrometallurgy**

Table 2. Direct comparison of the main recycling technologies described in this review.

	Pyrometallurgy	**Hydrometallurgy**	**Biometallurgy**	**Solvometallurgy (Ionic Liquid)**	**Solvometallurgy (DES)**
Advantages	Short process flow, low equipment requirements, strong operability	Low energy consumption, great versatility, high product purity, high recovery efficiency	Complete metal recovery, simplicity, cost-effectiveness, low energy consumption, mild conditions	Nonflammable, low volatility, tunable	Nonflammable, low recovery cost, green process, cheap and easy preparation, low toxicity
Disadvantages	High energy consumption, poor metal purity, difficulty in lithium recovery	Need to dispose of large amount of acid and toxic wastewater, long recovery process	Long processes and low kinetics, vulnerability to pollution	Expensive	Difficulty to scale-up, low cathode/DES ratio
Applied at industrial level	Yes	Yes	No	No	No
Main source of pollution	Emission of polluting gases and production of slags	Release of toxic gases (e.g. NO_x, SO_x, Cl_2)	-	-	-

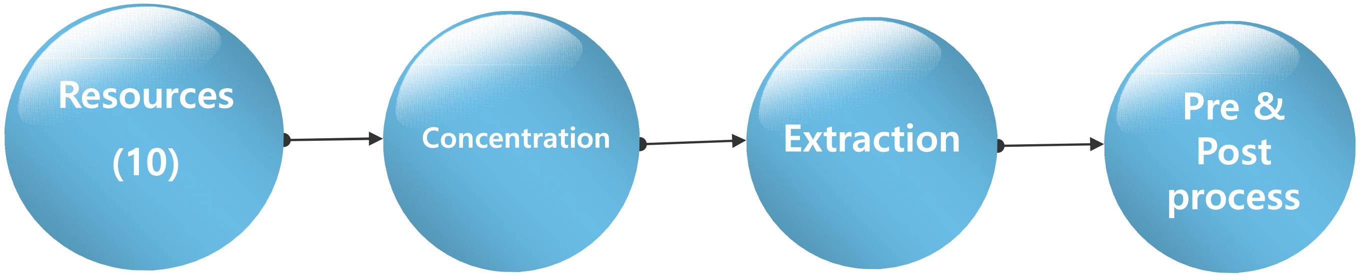
Source: https://doi.org/10.3390/batteries10010038

Ongoing Project

Green Desalination Research Lab.

- Project title: World Top Class Lab. Project funded by KICT
- Periods : 2023~2032 (9 year)
- Budget : about 270,000 euro/year

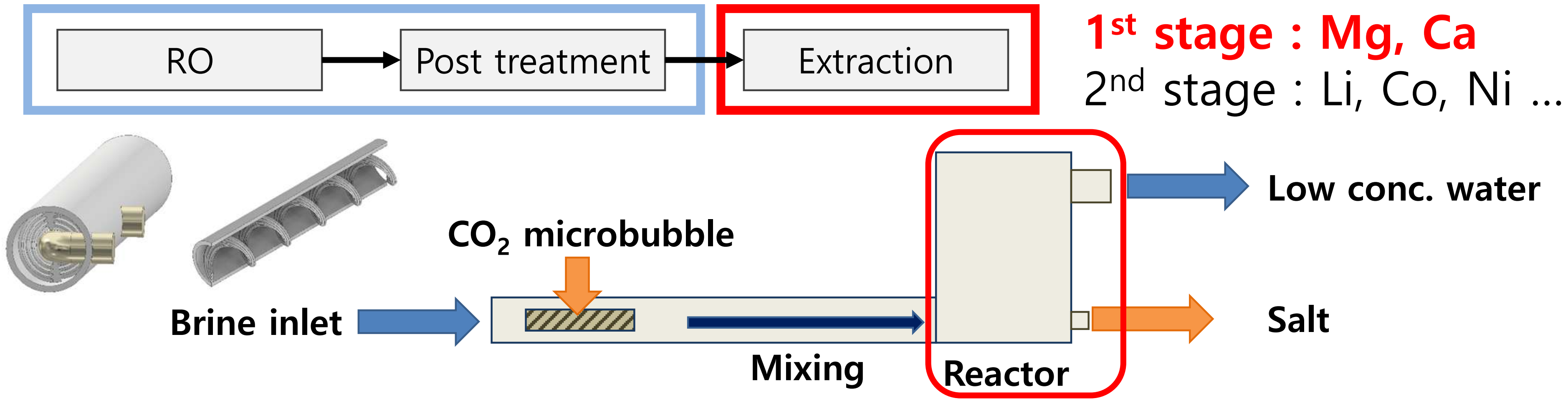
'VALUE in BRINE' is an innovative technology research lab. to circulate minerals & metals from brine for low carbon emission.



- Rb, Br, Mg, Ca, Li, K, Ag, F, Si, Cu
- MD, MDC, NF, Advanced RO
- CDI, MDC, ED
- Anti-Scale, Analysis, pH sensing, Materials

Research case 1 – Development of a resource recovery reactor in brine

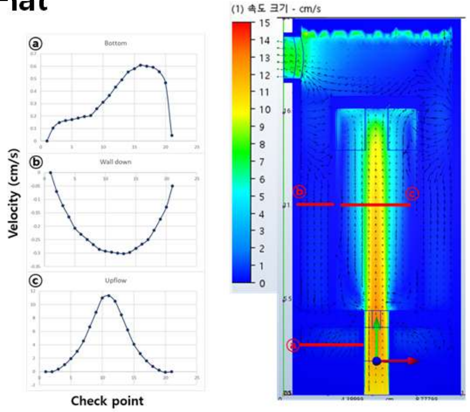
- **Development of a resource recovery reactor in brine**

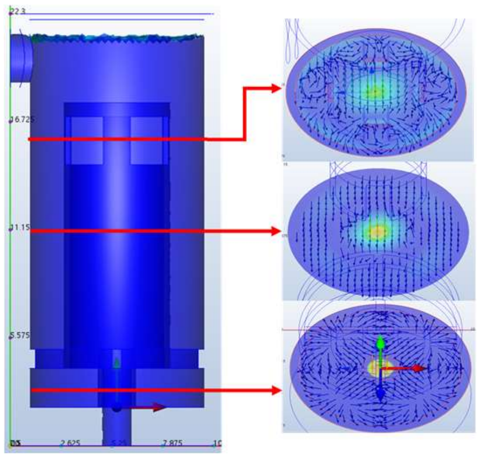


- **Research implementation method**
  - Reactor design using 3D CAD (Computer Aided Design)
  - Design verification through CFD (Computational Fluid Dynamics)
  - Lab scale reactor build-up using 3DP(Three dimensional printer) Manufacturing and verification of lab scale reactor

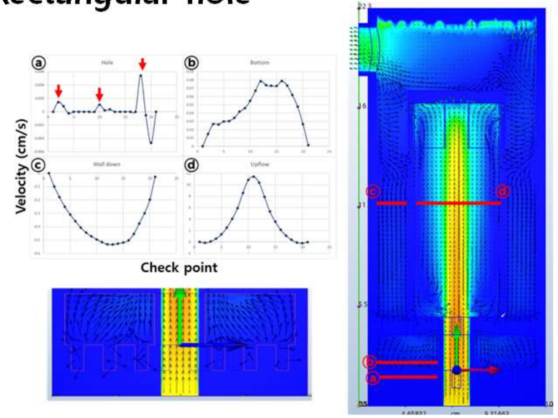
Results

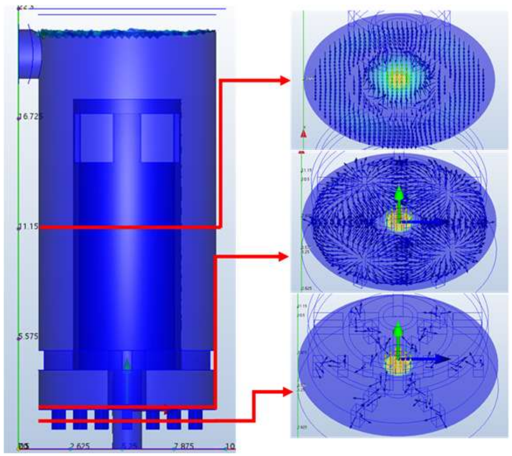
1. Flat



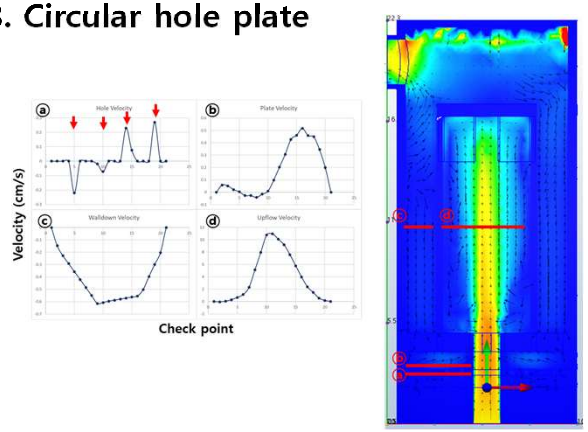


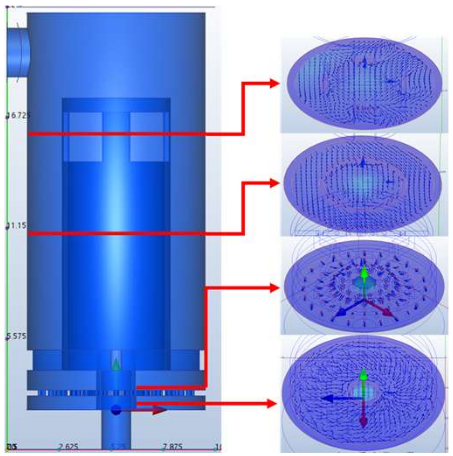
2. Rectangular hole





3. Circular hole plate

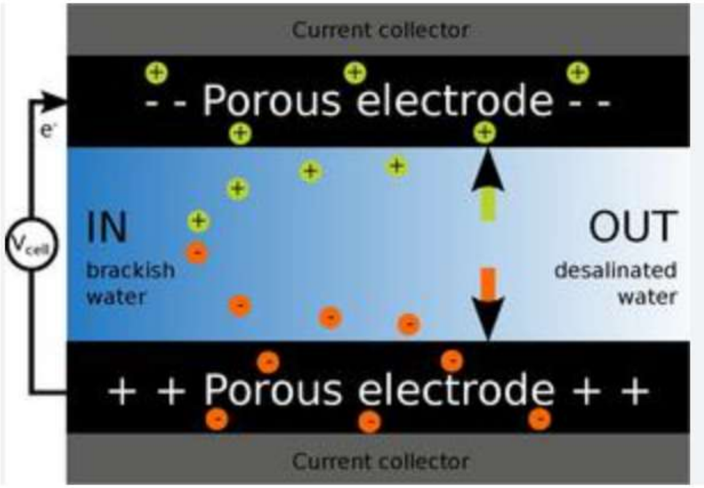




Research case 2 – Development of electrode manufacturing recipe for CDI

CDI

- A technology that removes ionic components in a solution through adsorption/desorption by applying a low voltage to a porous carbon electrode based on the principle of electric double layer formation.



Resource recovery technology

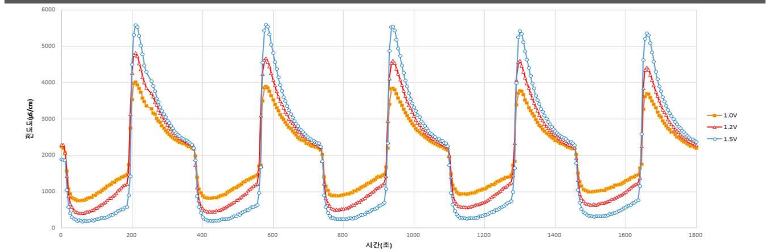
- Target ions: Li, Mg, Sr, Rb, etc. Battery/energy materials
- Concentration technology: Membrane separation, electrode-type desalination, evaporation concentration technology
- Separation technology: Adsorption, solvent extraction, crystallization technology
- Purification technology: Impurity removal technology, demand-tailored processing technology
- Development of electrode manufacturing technology utilizing waste resources such as biochar
- Improving the recovery rate of produced water and selectively separating valuable resources in concentrated water by utilizing electrochemical mechanisms
- Selection of usable valuable resources

Results

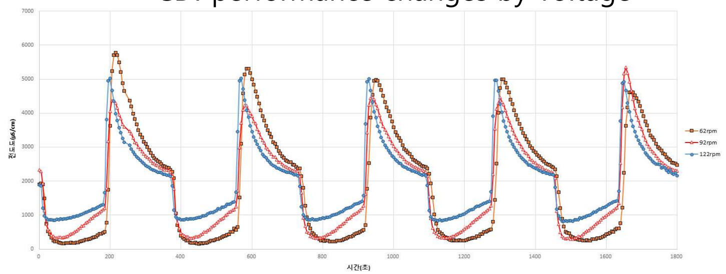
Performance evaluation by driving conditions and derivation of optimal driving conditions

- The results of the performance evaluation of the laboratory-scale CDI device under different operating conditions showed that the lower the flow rate and the higher the voltage, the higher the salt removal and concentration efficiency.
- Through response surface methodology (RSM), the optimal CDI operating conditions were derived in terms of production quantity and salt removal rate: voltage 1.5 V, flow rate 200 mL/min, adsorption/desorption ratio 1:08.

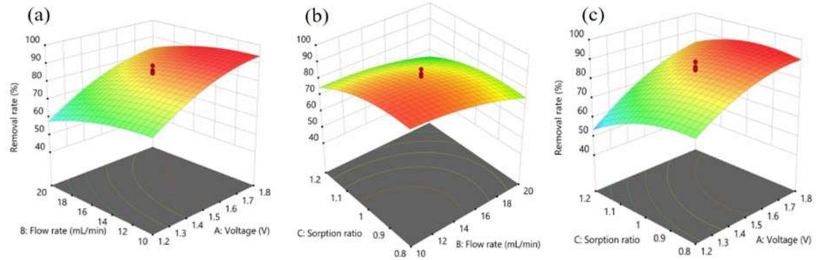
Performance evaluation by operation conditions



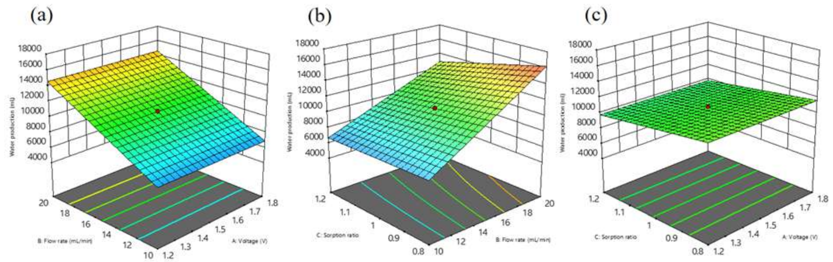
<CDI performance changes by voltage>



Deriving optimal operating conditions using response surface methodology (RSM)



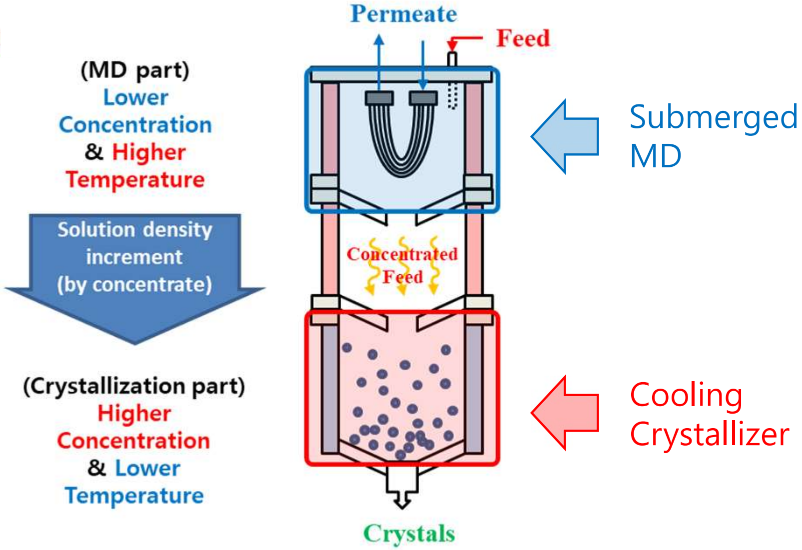
<Influence of three major factors on salt removal rate>



Research case 3 – Development of membrane crystallization technology

Fractional-submerged membrane distillation crystallizer(F-SMDC)

- Technology based on existing membrane distillation technology but for effective resource recovery
- Technology utilizing temperature/concentration gradient and gravity caused by density difference of solution
- In the lower case, crystal recovery is achieved by maintaining high concentration/low temperature conditions

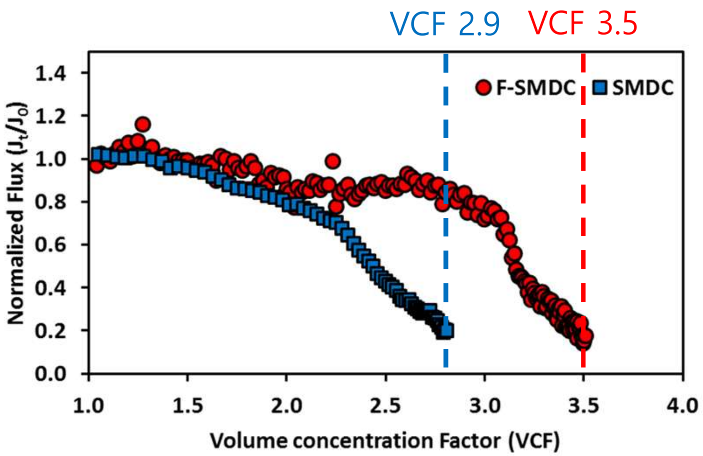


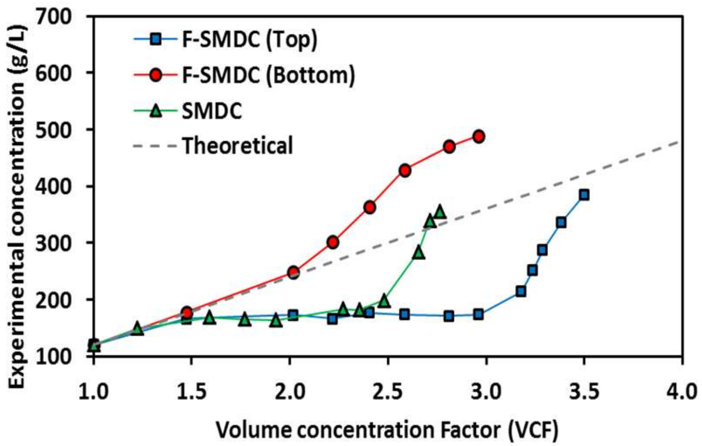
- No need for circulation of feed solution
- Reduction of heat loss
- Multifunction reactor (membrane reactor, crystallizer, feed tank)

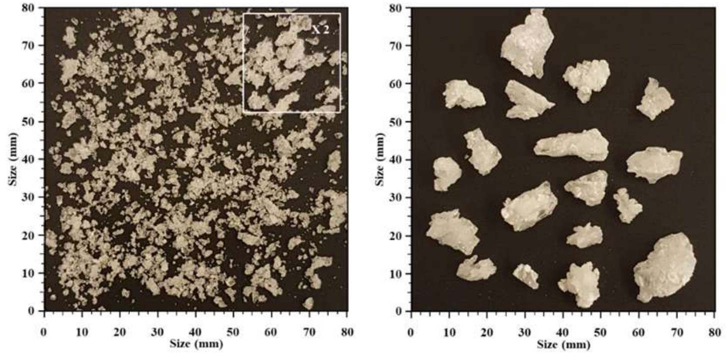
- Stimulation of nucleation by temperature control

Results

F-SMDC mode vs. S-MDC mode

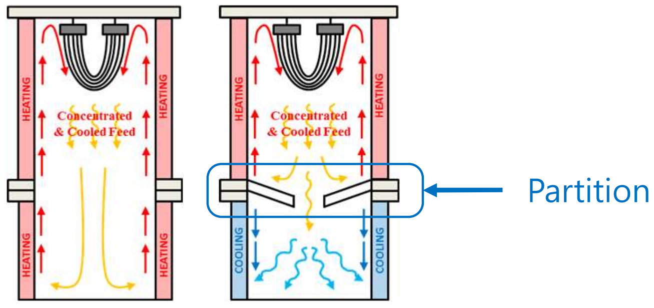






Feed solution : 120 g/L Na_2SO_4

< sodium sulfate crystals produced >



(a) S-MDC (b) F-SMDC

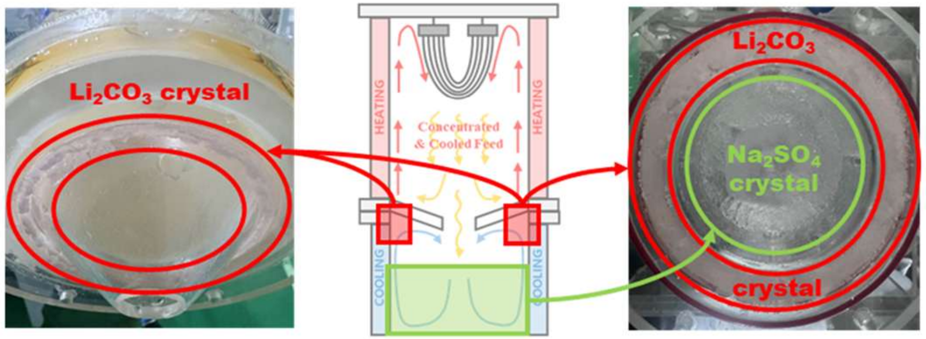
< Convection current by heating/cooling >

❖ Partition prevented the feed solution mixing by convection (like trap)

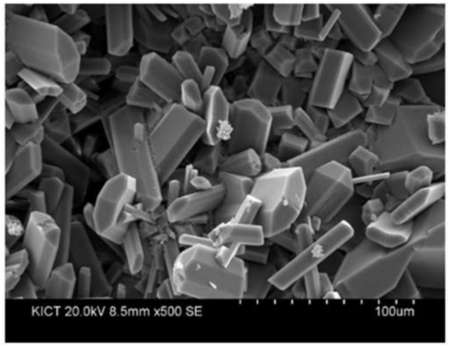
Recovery of Li_2CO_3 by F-SMDC

F-SMDC was our starting point for lithium recovery, but challenges with selectivity emerged

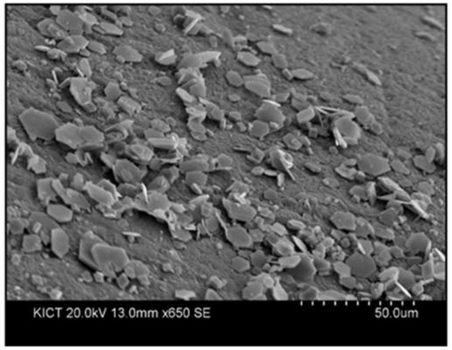
[Floating crystals in reactor]



[Li_2CO_3 crystals cluster deposited on the reactor wall at bottom side]



< Li_2CO_3 crystals >



< membrane surface >

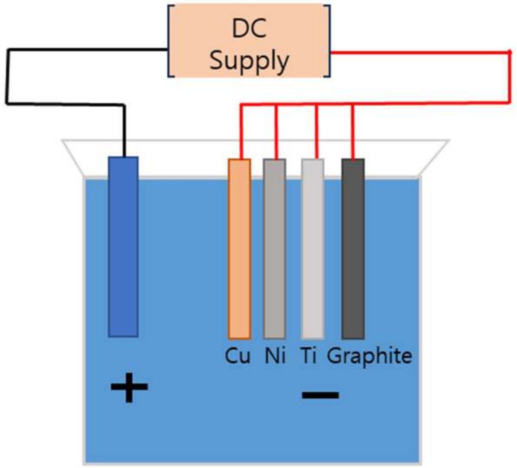
Li_2CO_3

✓ Crystallization at the top (60°C),
- (i) Deposition on membrane surface
- (ii) Fouling & flux decline
- (iii) Interruption of downward stream
  → Interruption of CG Formation

❖ Limitations
- Low Selectivity
- Not suitable for ions which have low solubility @ higher temperature

Selective Recovery

Mixed Ion Electrocrystallization



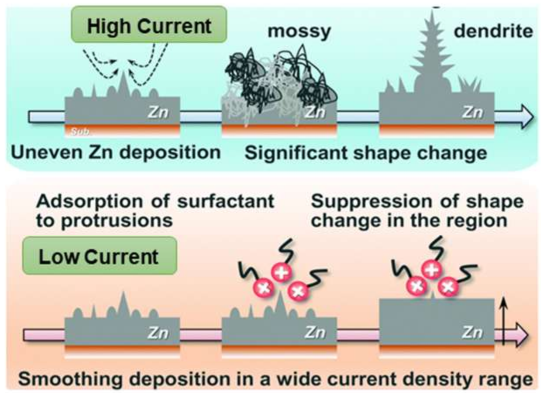
Stimulated Cu^{2+} , Ni^{2+} , Co^{2+} , Mn^{2+} solution with different cathodes

Selective Deposition

Half-reaction (reduction)	Standard reduction potential, E° vs SHE (V)
$Li^{+} + e^{-} \rightarrow Li(s)$	−3.050 V
$Mn^{2+} + 2\,e^{-} \rightarrow Mn(s)$	−1.180 V
$Co^{2+} + 2\,e^{-} \rightarrow Co(s)$	−0.277 V
$Ni^{2+} + 2\,e^{-} \rightarrow Ni(s)$	−0.280 V
$Cu^{2+} + 2\,e^{-} \rightarrow Cu(s)$	+0.337 V

Potential Difference is exploited in our metal recovery process

Electrocrystallization Morphology



Analyze Crystal Size and Shape

Basic Lithium Electrochemical Test - Results

< Chemical precipitation of Li_2CO_3 after 1 h at 0.5 M LiCl with 0.3 M Na_2CO_3>

< At 2V, Denser Li_2CO_3 precipitation layer forming along the beaker bottom and wall after 1 h at 0.5 M LiCl with 0.3 M Na_2CO_3>

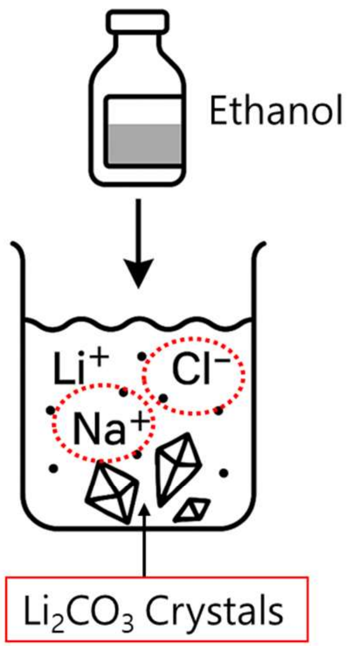
- ❖ Results confirm potential but are still preliminary and ongoing.
- ❖ Preliminary images (above) were taken after 1 h at 2.2 V under heat (no stirring) and chemical precipitation at 50 °C with stirring at 150 rpm
- ❖ Although results are still inconclusive, these trials will be compared to evaluate the effect of heating.

Next steps:

- ❖ Incorporate a reference electrode to measure potentials
- ❖ Explore pulsed current modes to improve nucleation and control.

Anti-Solvent Crystallization

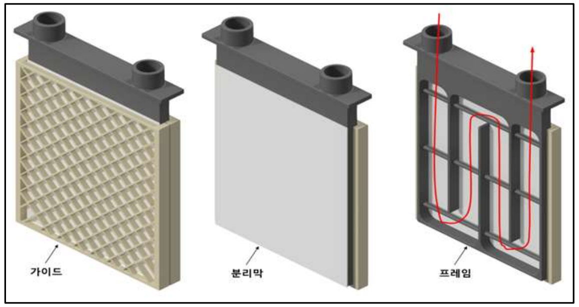
- High concentrations of other ions (Eg. Na^+, Cl^-) make it difficult to separate lithium selectively by electro-crystallization alone.
- Currently exploring anti-solvent crystallization to reduce the solubility of lithium carbonate and drive its precipitation while leaving most interfering ions in solution
- Other interfering ions→ ethanol reduces Li_2CO_3 solubility → MD to recycle ethanol.



❖ Anti-Solvent Crystallization

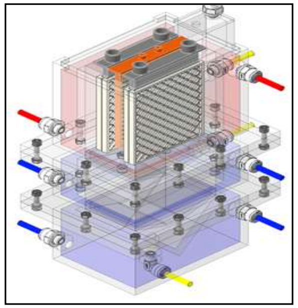
Design of a High-Concentration System Using a Cassette-Type Membrane Module

- ✓ **Enabling individual membrane replacement allows maintenance without process interruption.**
- ✓ **Direct heating via the Joule heater and heat exchanger minimizes heat loss and energy consumption.**



<Cassette-Type Flat Sheet Membrane Module >

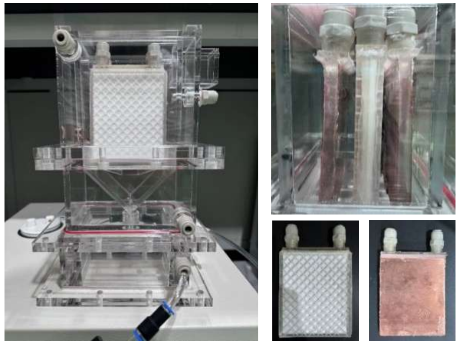
<Joule Heater and Its Installation Position>



<Reactor>

Prototype

- ✓ **The reactor places the membrane module and Joule heater at the top, with concentrated feedwater collected at the bottom.**
- ✓ **Automated intermittent heating minimizes energy use and enhances crystallization and resource recovery (under evaluation).**



<Prototype>


발 명 보 고 서

<Patent(on-going)>

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International Networking

WTCL KICT

Europe
- EURECAT
- MOU ('23.05.)

U.S.A.
- YALE Univ.

Middle East
- DTRI(WTIIRA)
- Qatar Univ.

Australia
- UTS

Promoting collaboration with various institutions worldwide and advancing international joint research

Technology in the Market

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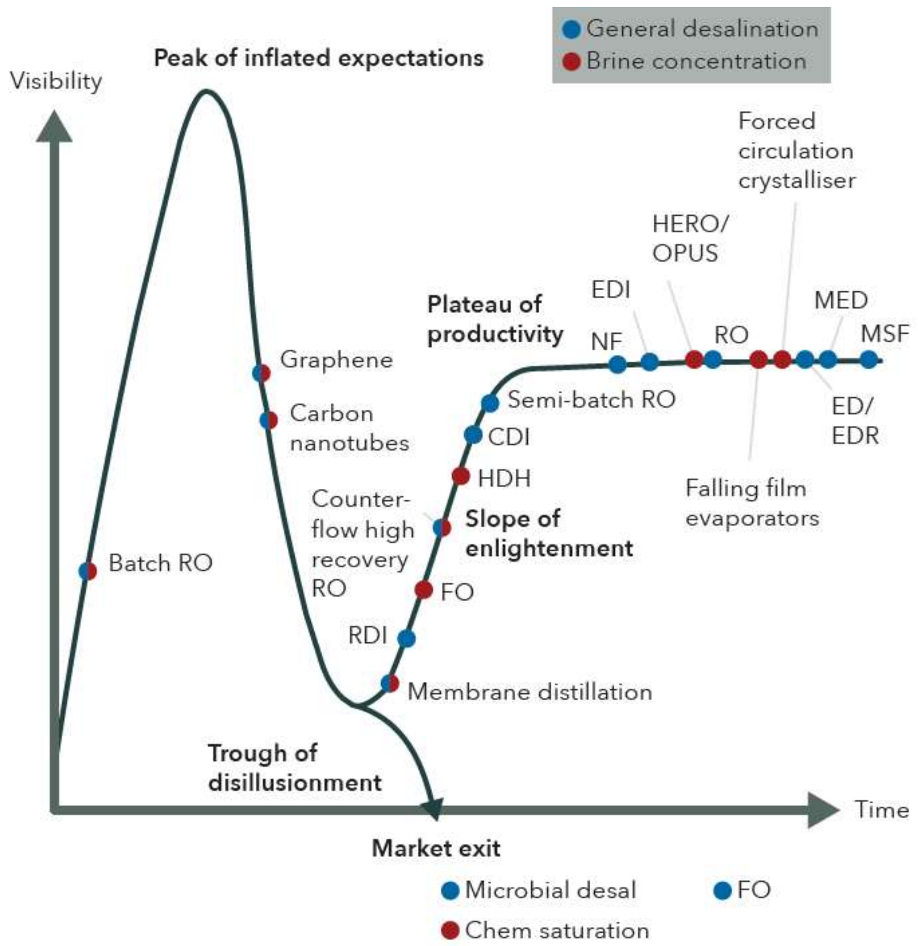
- **Success and failure of technology**
- **We need collaboration**



Source: GWI DesalData

Experience

EmerG0

Targeted Call: HORIZON-CL6-2025-01

Title: A PLATFORM FOR TRACKING AND REDUCING PERSISTENT AND EMERGING POLLUTANTS TOWARDS ZERO POLLUTION IN FOOD AND DRINK SYSTEMS

Participants: 19
Coordinator: EURECAT in Spain

Your Project Idea

Water-Energy-Resource Nexus

Targeted Call: HORIZON-CL5-2026-03-D2/HORIZON-CL5-2026-03-D3 (?)

Main Objectives
To develop **carbon reduction technologies utilizing urban water resources** based on the **circular economy** concept. The project aims to create an integrated **water-energy-carbon nexus system** that captures and reuses CO_2 through innovative water treatment and resource recovery processes.

Idea Briefly Explained
The research focuses on using **urban wastewater and seawater desalination brine** as carbon capture and utilization media. By combining **membrane crystallization, electrochemical conversion, and AI-based process optimization**, the technology will contribute to **low-carbon cities** and **sustainable water management** aligned with the **EU Green Deal** and **carbon neutrality goals**.

Water-Energy-Resource Nexus (Circular Economy)

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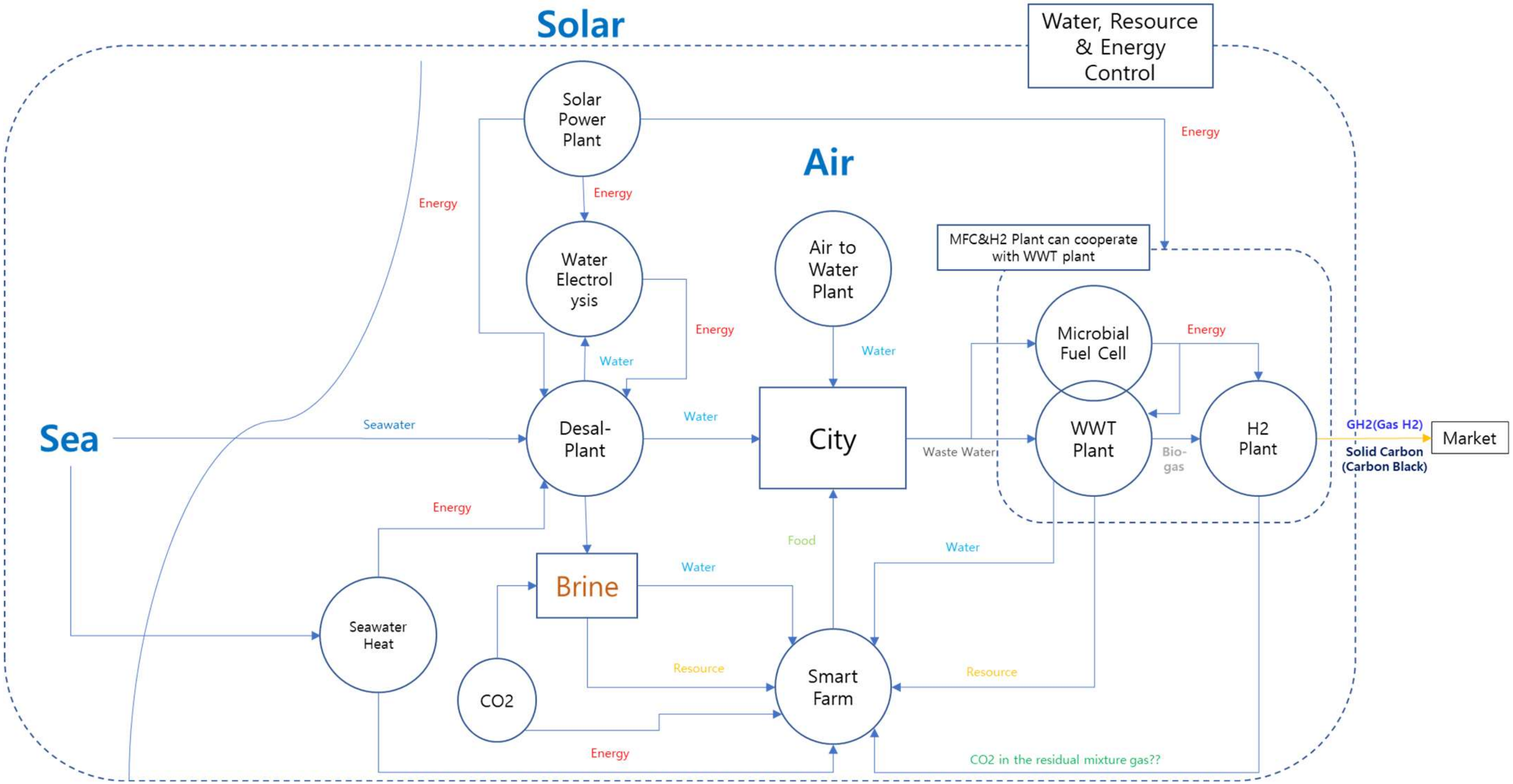

Water-Energy-Resource Nexus (Circular Economy)

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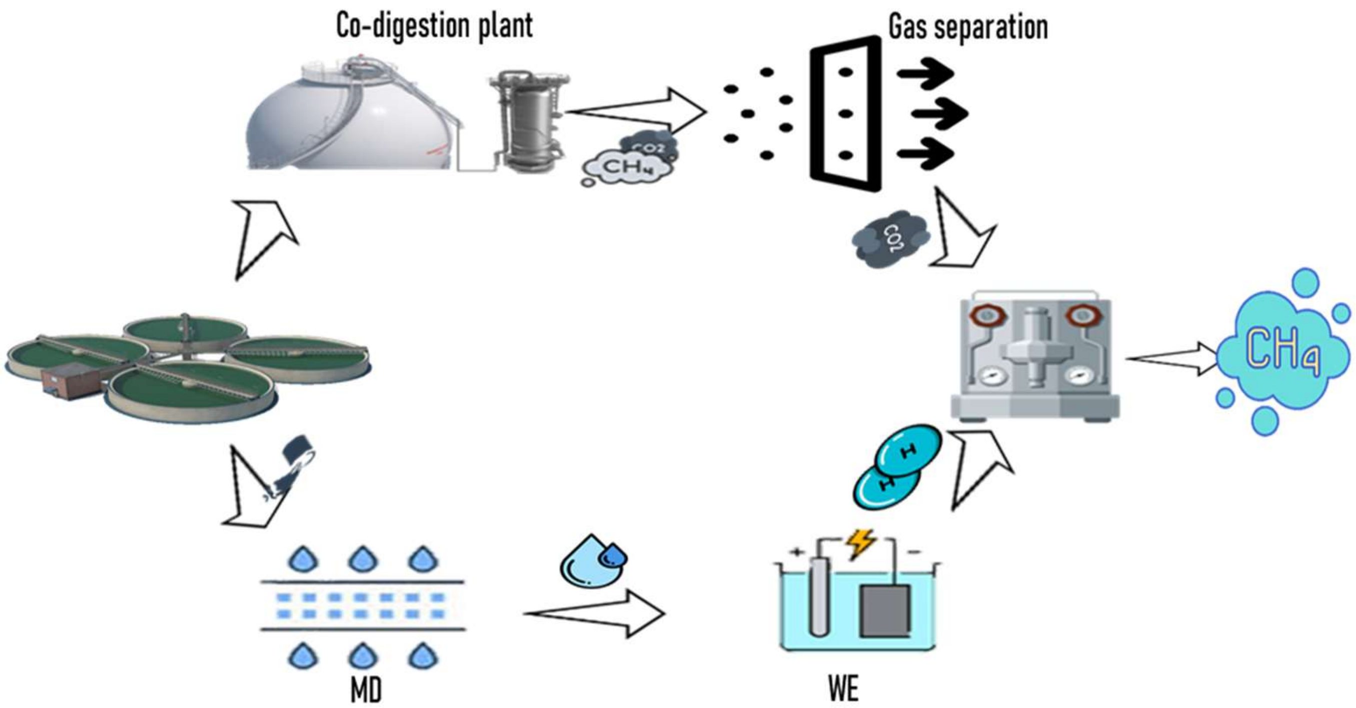

- Process Design
- Materials
- Energy Control
- Digital Technology

Profile You are Seeking and Why

IF YOU PRESENT A PROJECT IDEA

We are seeking **European partners**—including **municipal authorities, research institutes, and universities**—interested in developing **CO_2 reduction technologies through circular water systems**.
Ideal partners should have expertise in **urban water management, carbon capture and utilization (CCU), life-cycle assessment, or digital twin technologies** for sustainable city applications.

Collaboration aims to design and demonstrate **urban-scale water-carbon nexus solutions** contributing to **carbon neutrality and resource circulation**.

KERC
Korea-EU Research Centre

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