2023 Membrane Technology
CONFERENCE & EXPOSITION

February 20-23, 2023
Knoxville, TN

Brine Mining

Richard L. Stover, Ph.D.

AMTA
American Membrane Technology Association

American Water Works Association

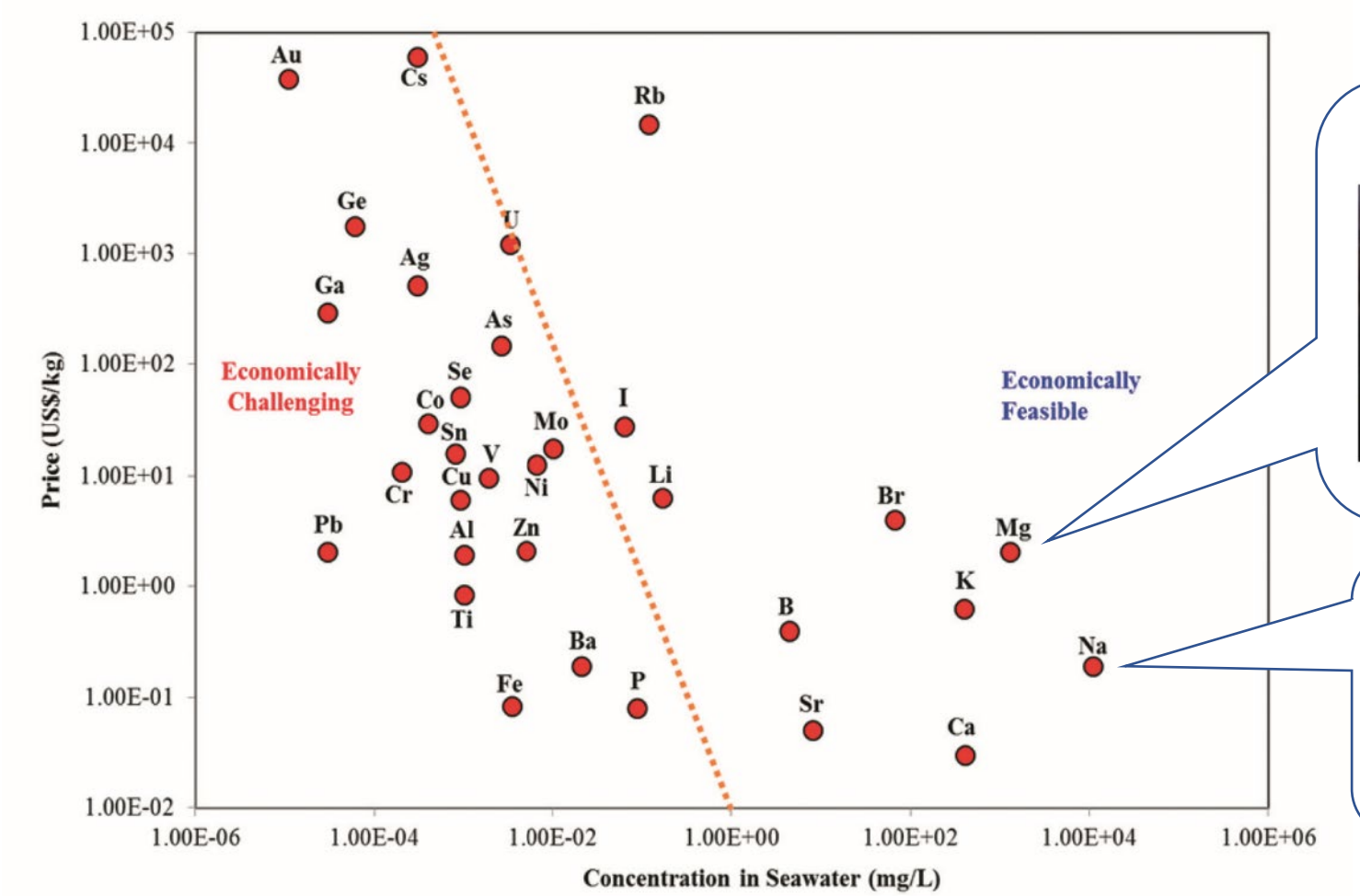
Brine Mining?

1. What valuable minerals are in seawater?
2. What makes or breaks a traditional mining business?
3. Does new technology or market opportunity increase the prospects for brine mining?

… finding an income stream from salt seems the natural way to offset the cost of energy for the desalination process.

- Christopher Gasson

Minerals in Seawater



Dow Process



Dow Freeport Plant A 1964 (Dow Chemical)

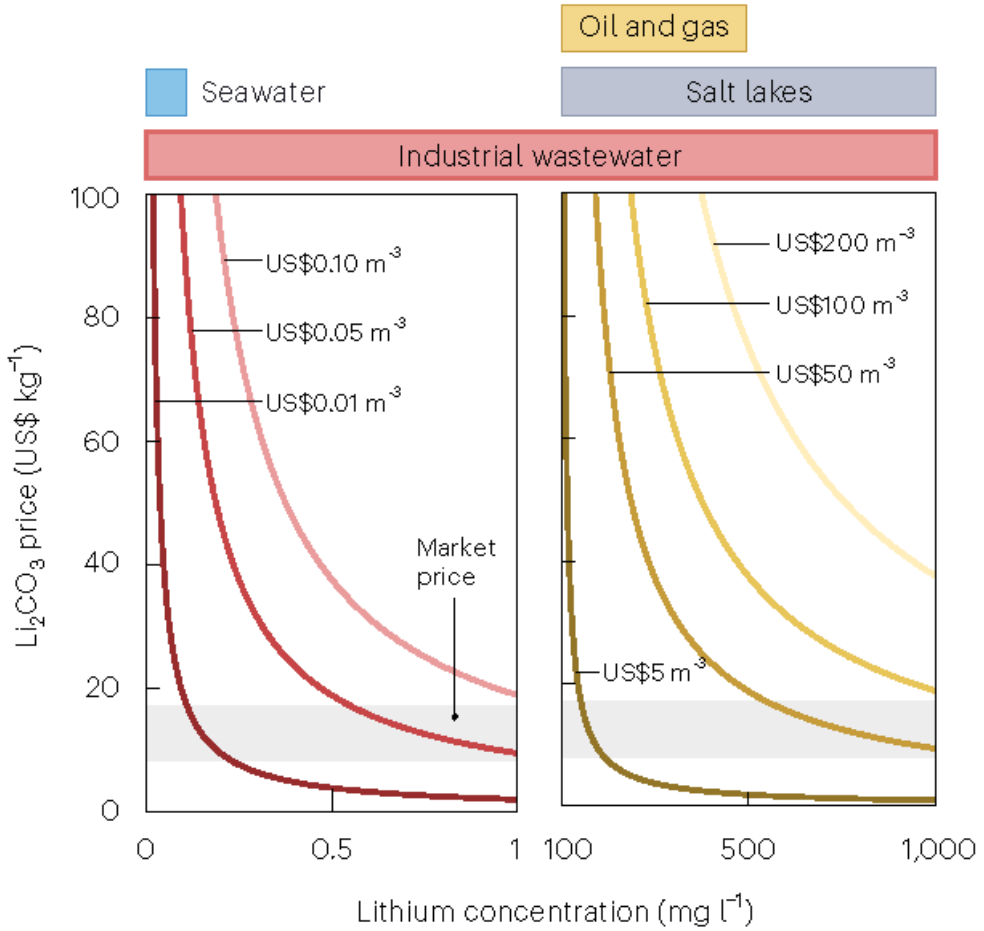
Chlor-alkali industry $63B

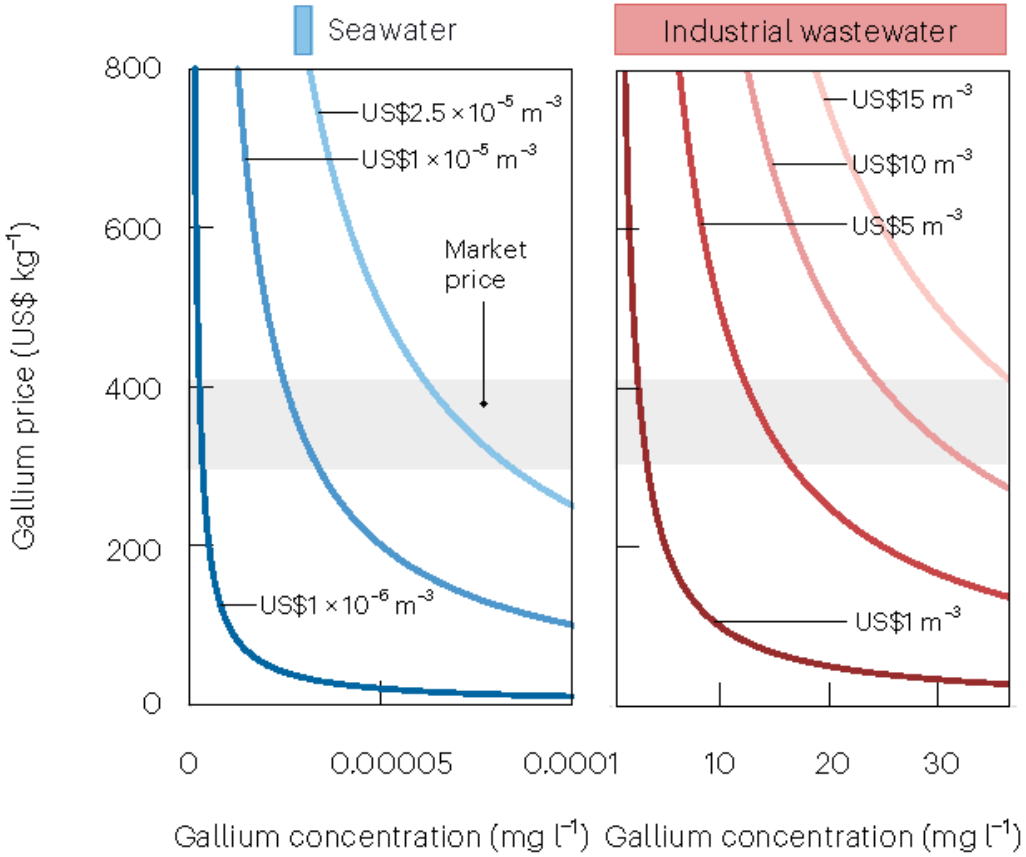
NaCl → caustic soda, chlorine, soda ash

Asia and South America

Loganathan, P., Vigneswaran, G. Environ. Sci.: Water Res. Technol., 2017

Minerals in Saltwater



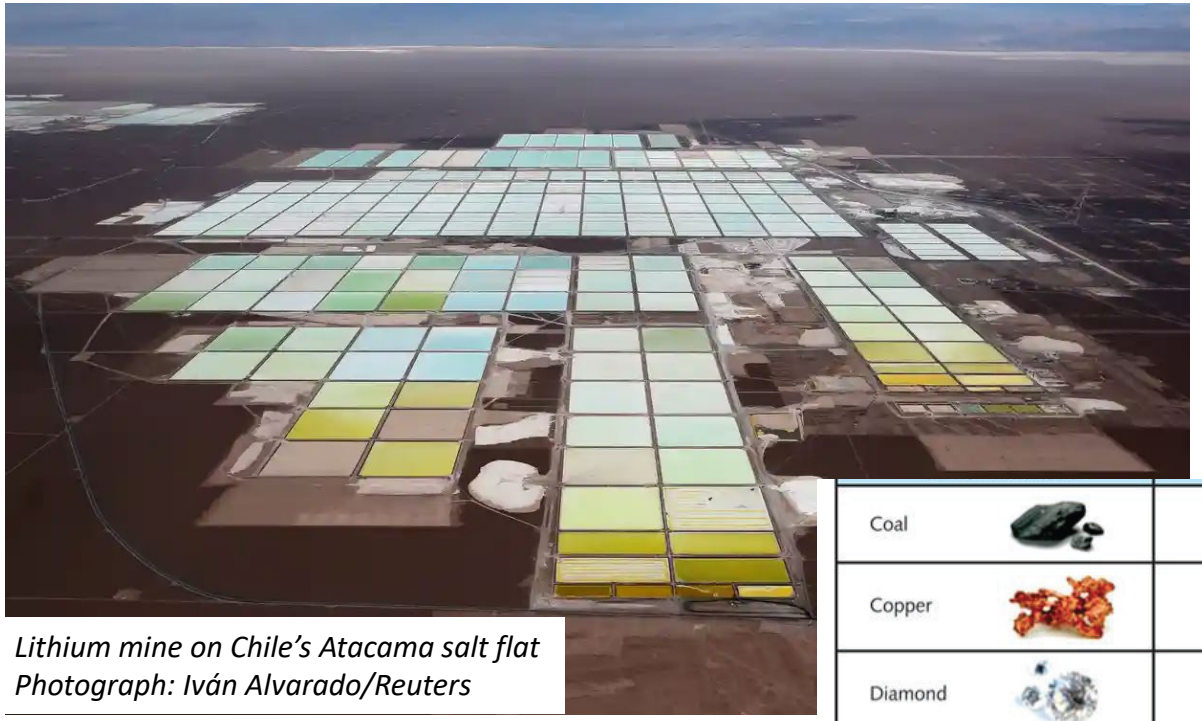


Lithium and Galium

- Seawater mining only viable if desal costs plummets, or
- The price of lithium skyrockets.
- More viable from industrial waste streams

Ryan M. DuChanois, Nathanial J. Cooper, Boreum Lee, Sohum K. Patel, Lauren Mazurowski, Thomas E. Graedel & Menachem Elimelech

Conventional Mining



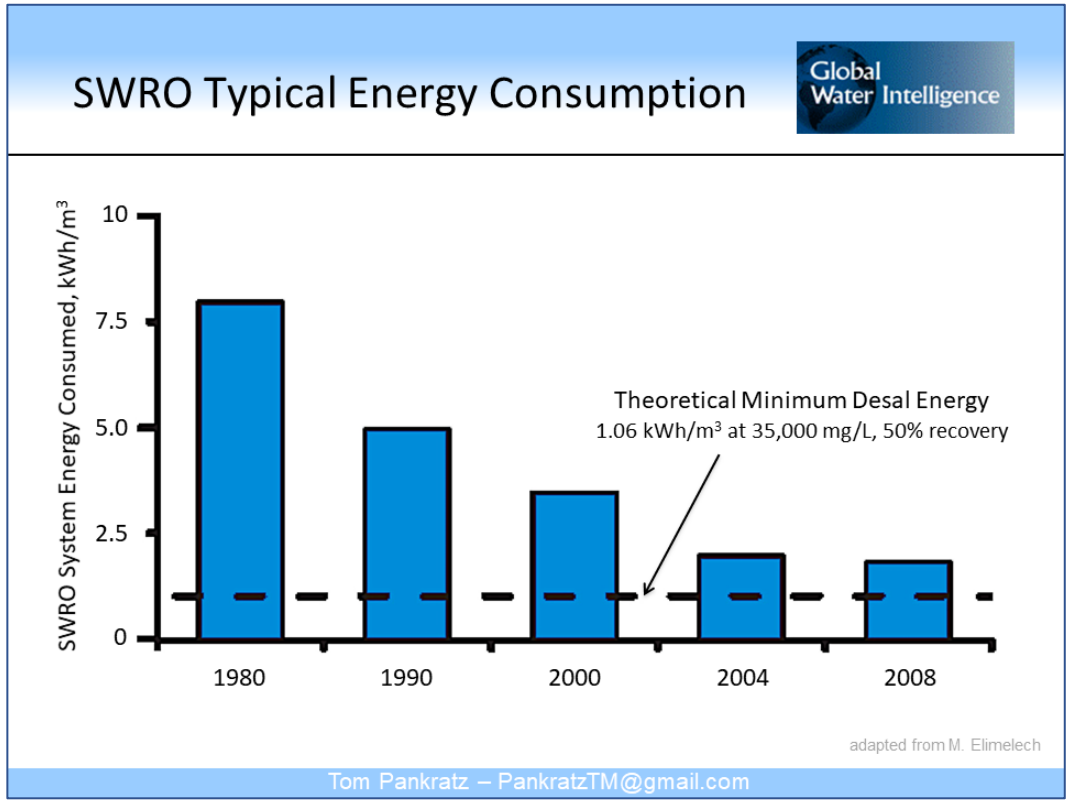
Lithium mine on Chile's Atacama salt flat
Photograph: Iván Alvarado/Reuters



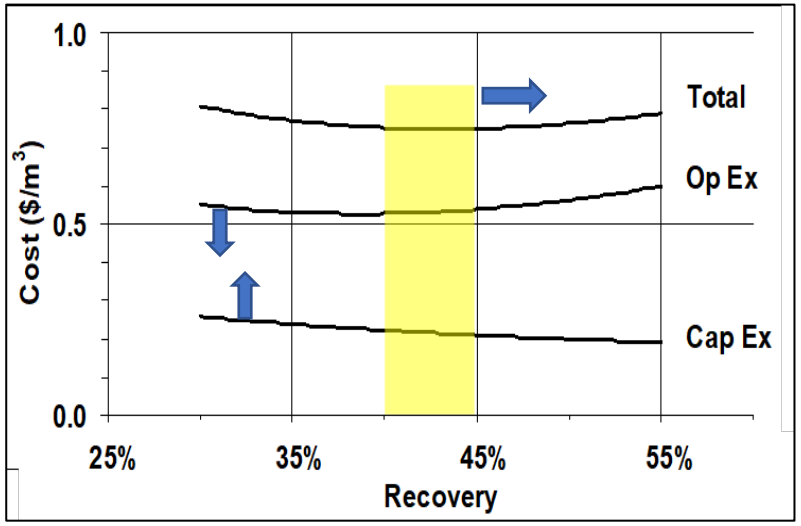
Source: Frost & Sullivan[4]

- Extraction, concentration, purification, distribution
- Water use
- Water stressed regions
- Oppty for water treatment
  - Eliminate solar ponds
  - Mine tailings ponds
  - MLD/ZLD of wastewater

New Technologies and Opportunities



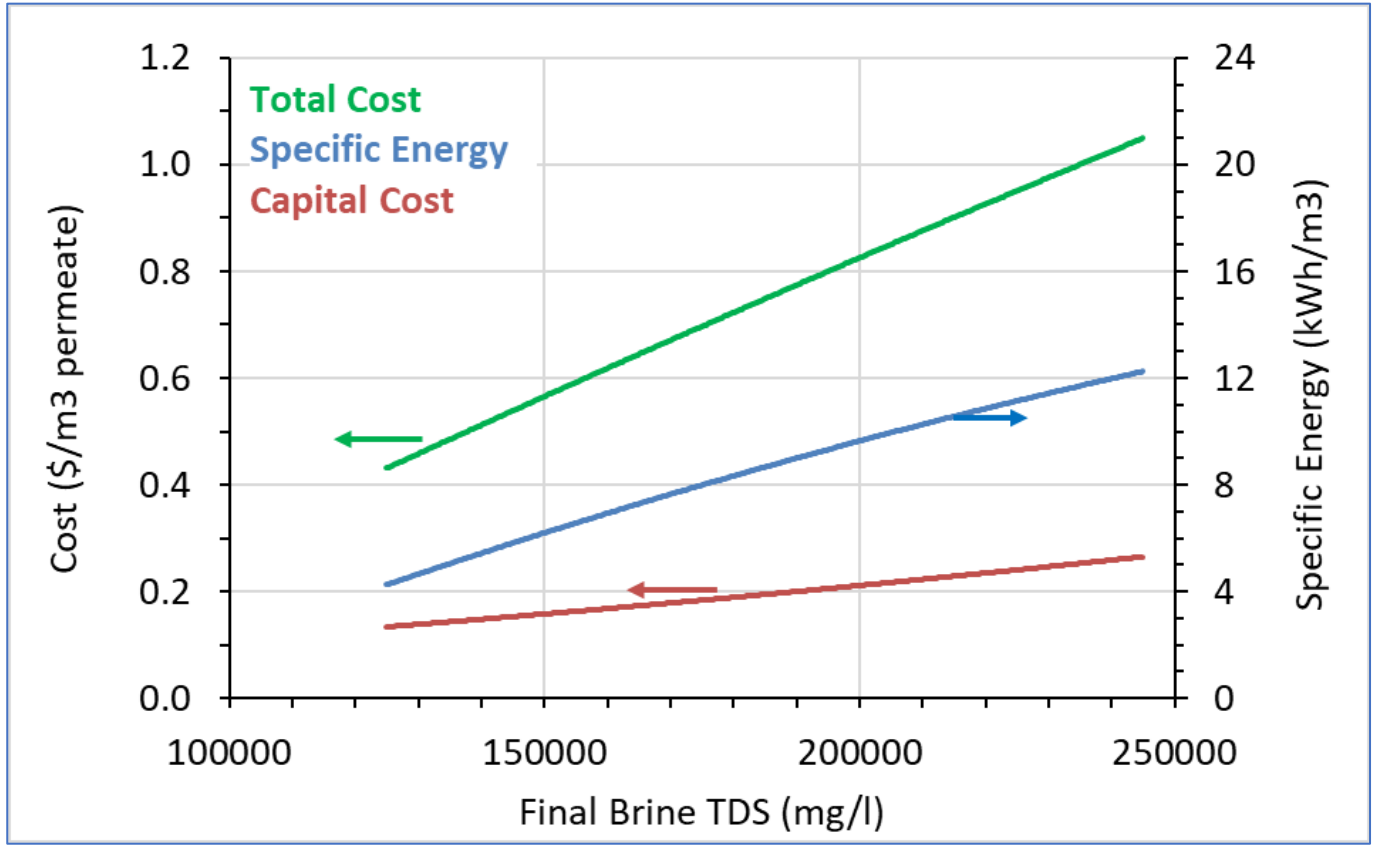
- Technology advances
- Brine proliferation – 140M m^3/day by 2025 *(Amane)(but not in CA)*
- Cost reductions and increases



SWRO trends

- OPEX ↓
- CAPEX ↑
- Recovery ↑
- Brine TDS ↑

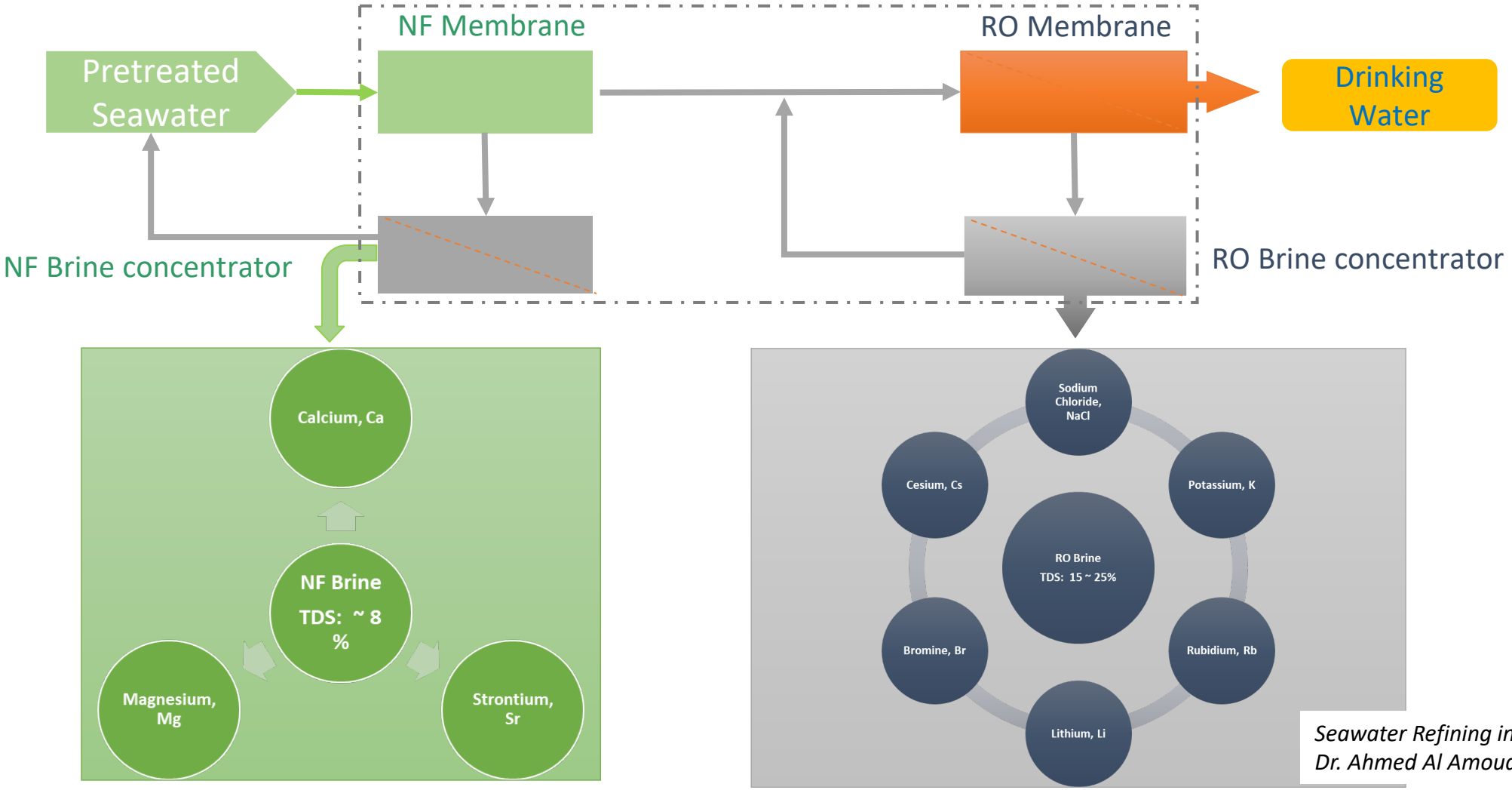
New Technologies and Opportunities



15,000 m3/d 65,000 mg/l TDS feed, 20 yr amort, 6% interest, $0.048/kWh

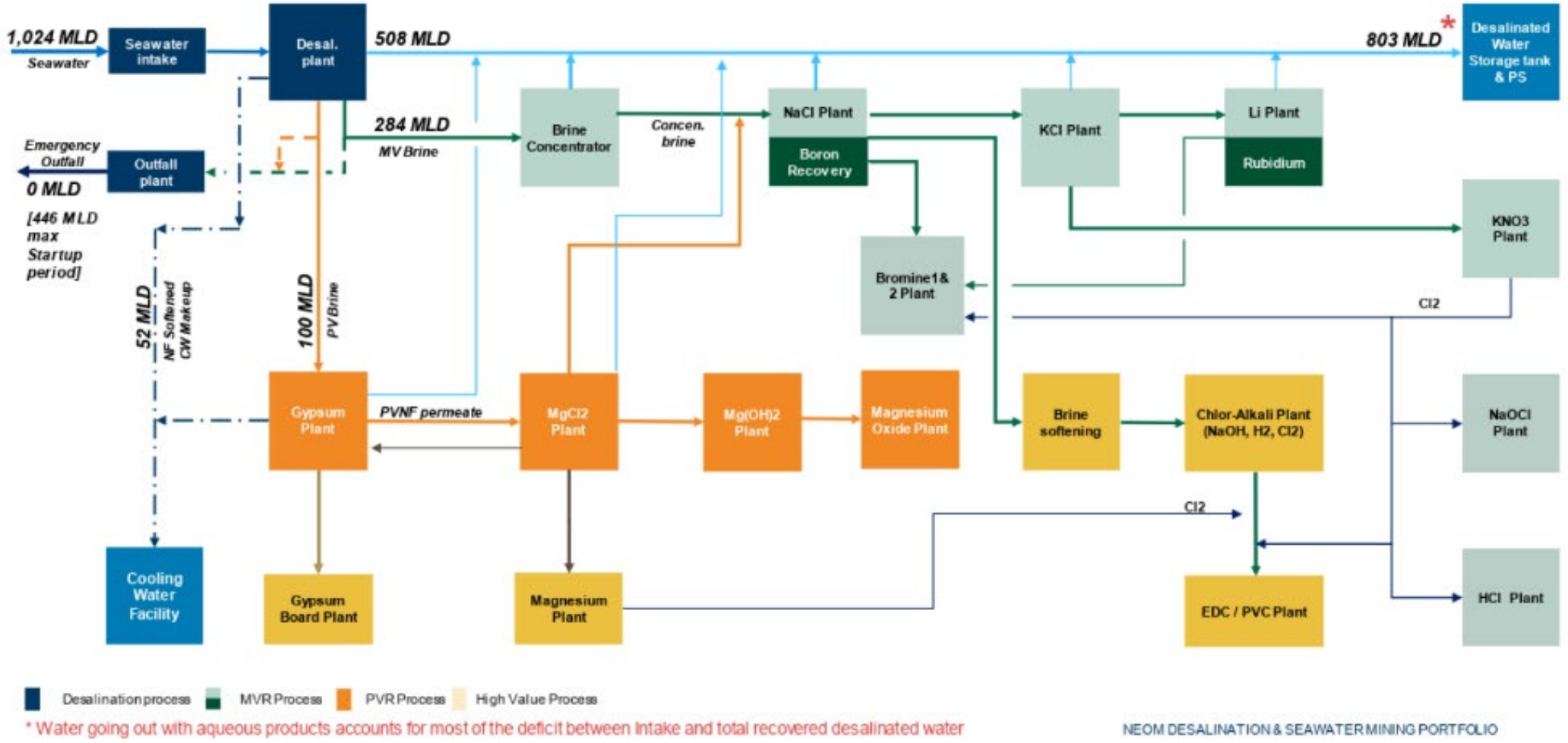
- Membrane brine desalination/concentration OARO / CFRO
- Permeate recovery from SWRO brine: 3-12 kWh/m^3, \$0.40-\$1/m^3,
- <1/2 the cost of evaporation

New Technologies and Opportunities



Seawater Refining in Saudi Arabia
Dr. Ahmed Al Amoudi, DTRI

New Technologies and Opportunities

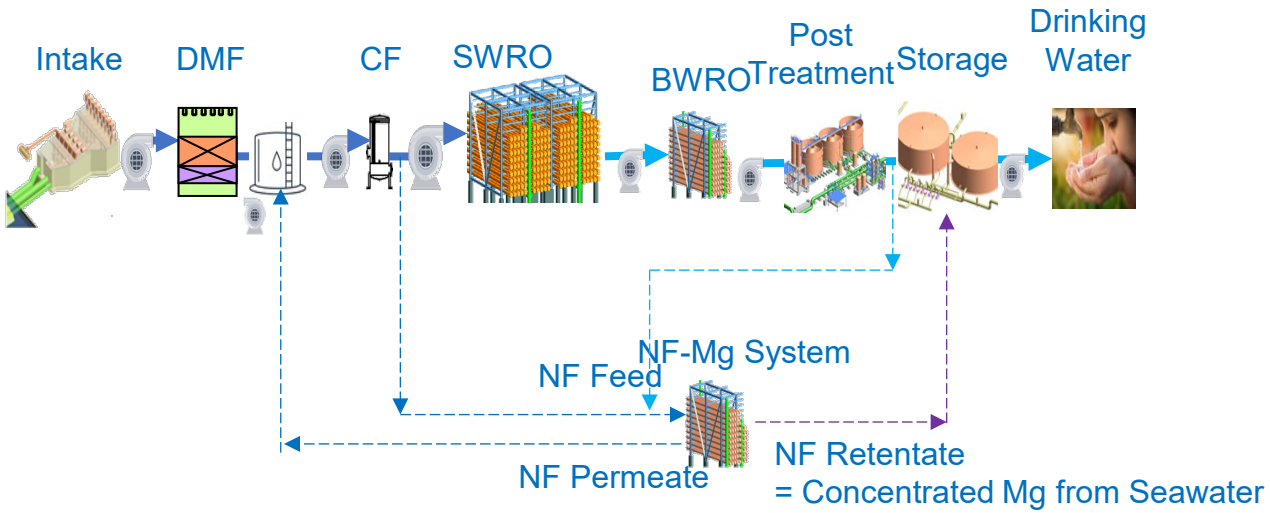


NEOM Desalination and Brine Processing
Robert Garner, NEOM

New Technologies and Opportunities

Shoaiba NF Project: System to Extract Mg from Seawater

Existing 400,000 m^3/d Desalination Plant



	Shoaiba Ph.4 Product Water*	Mg-enriched brine from NF	Final Drinking Water with Mg = 16.8~21.0ppm	
Ca	*16.0*	735	18.1	Ca
Mg	*0.0*	7,266	21.0	Mg
Na	*0.9*	648	2.8	Na
K	*0.1*	25	0.1	K
HCO3	*49.0*	106	49.2	HCO3
SO4	*0.0*	25,030	72.4	SO4
Cl	*1.5*	3,718	12.2	Cl
Sr	*0.0*	5.4	0.0	Sr
B	*1.0*	0.8	1.0	B
TDS	68.5	37,534	176.8	TDS

Seawater Refining in Saudi Arabia
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New Technologies and Opportunities

The Challenge

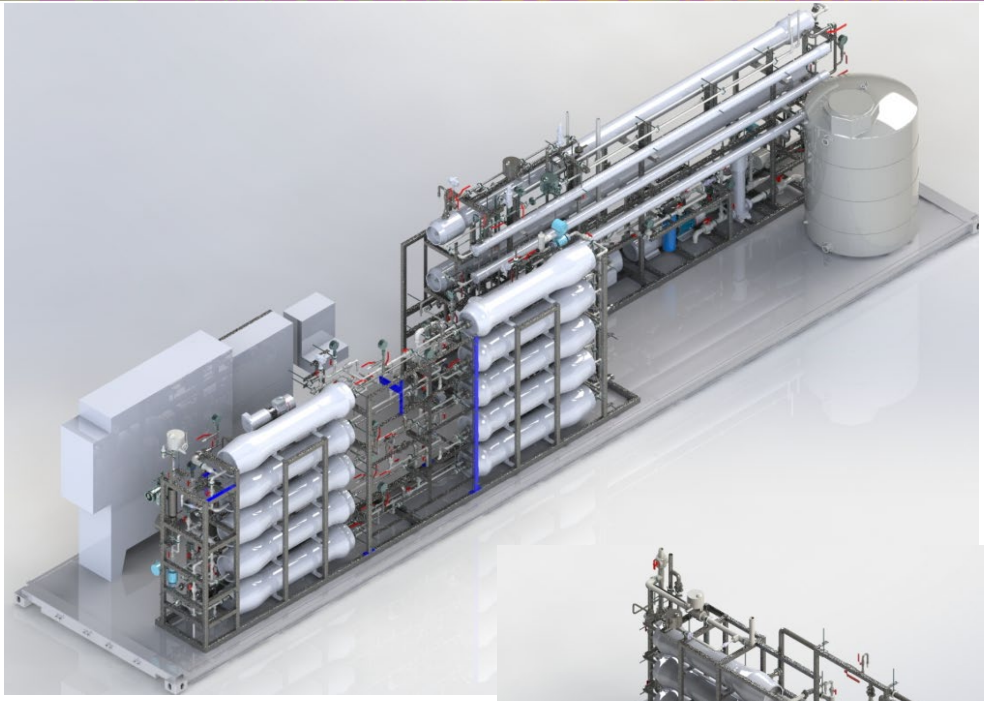
- Reduce **lithium** production to 20-30 min
- 15x concentration factor
- High hardness, silica, metals

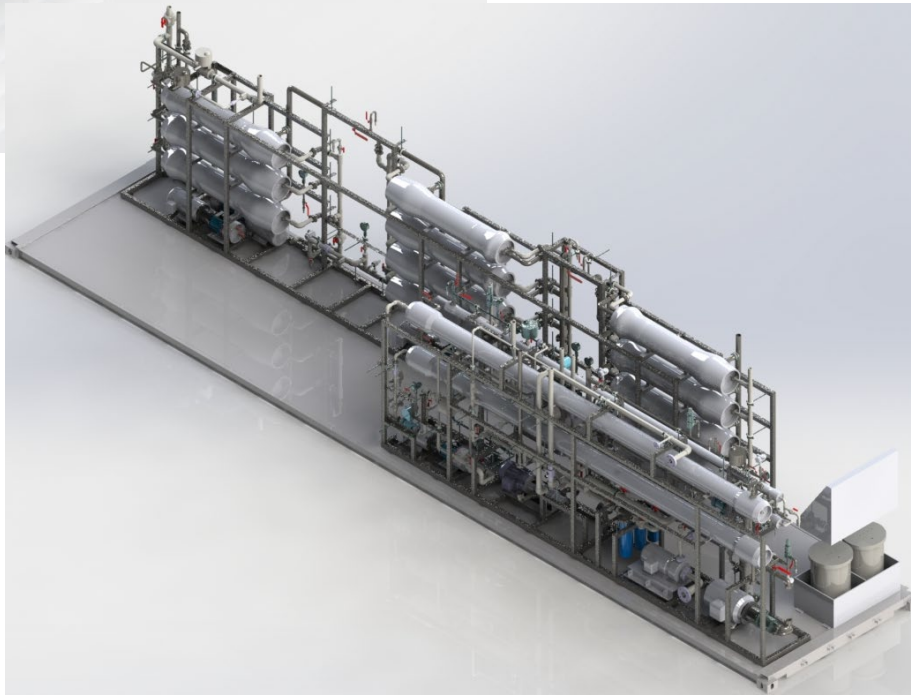
The Drivers

- Highly competitive lithium market
- Sustainability, robustness, cost-effectiveness
- Thermal technologies 2x too expensive

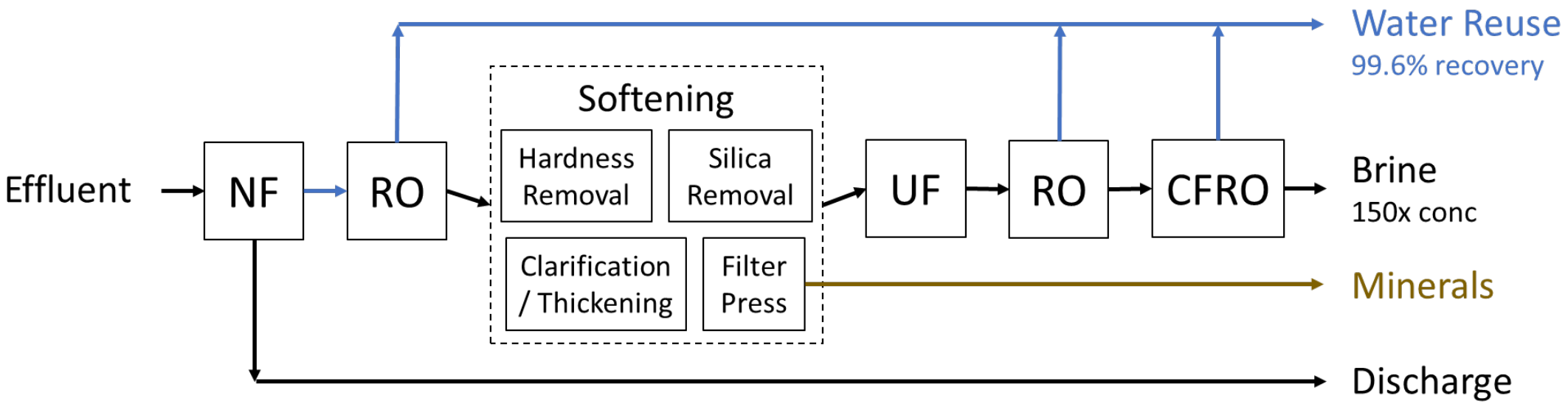
The Solution

- **CFRO** achieves 93% recovery
- **Lithium** from 1,000 to 15,000 mg/L
- TDS from 15,000 to 225,000 mg/L





New Technologies and Opportunities



- Membranes – continued movement away from thermal methods
- Performance – more selective membranes, smarter chemistry, AI/ML
- Sensitivity – advanced online sensors, microsensors
- Flexibility – robust to water changes / aging, direct coupled to renewable energy
- Reliability – fouling / scaling resistance, AI/ML
- Public acceptance and greater valuation of reuse

Challenges



EWM Enviro Water Minerals El Paso TX 2017

- ZLD “Refinery”
  - $60M facility
  - Offtaker contracts
  - sold for $5M



Antero/Veolia Clearwater Center Doddridge County, WV 2020

- Fracking Waste Recycling Center
  - $300M facility
  - $1.6B lawsuit
  - $242M award

Brine Mining

- How can brine be managed for optimal mineral production?
- Is brine mining a water challenge or an industrial process challenge?
- How can brine mineral production be matched with demand?
- Could water innovation make mining more viable/sustainable?
- Is this a way for the water industry to actually make money?

Desalinated seawater: $0.29 per ton. Scandium: $80M per ton.



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