

39TH REGIONAL MINING AND PHOSPHATE CONFERENCE
CHEMICAL PROCESSING SESSION · OCTOBER 15, 2026

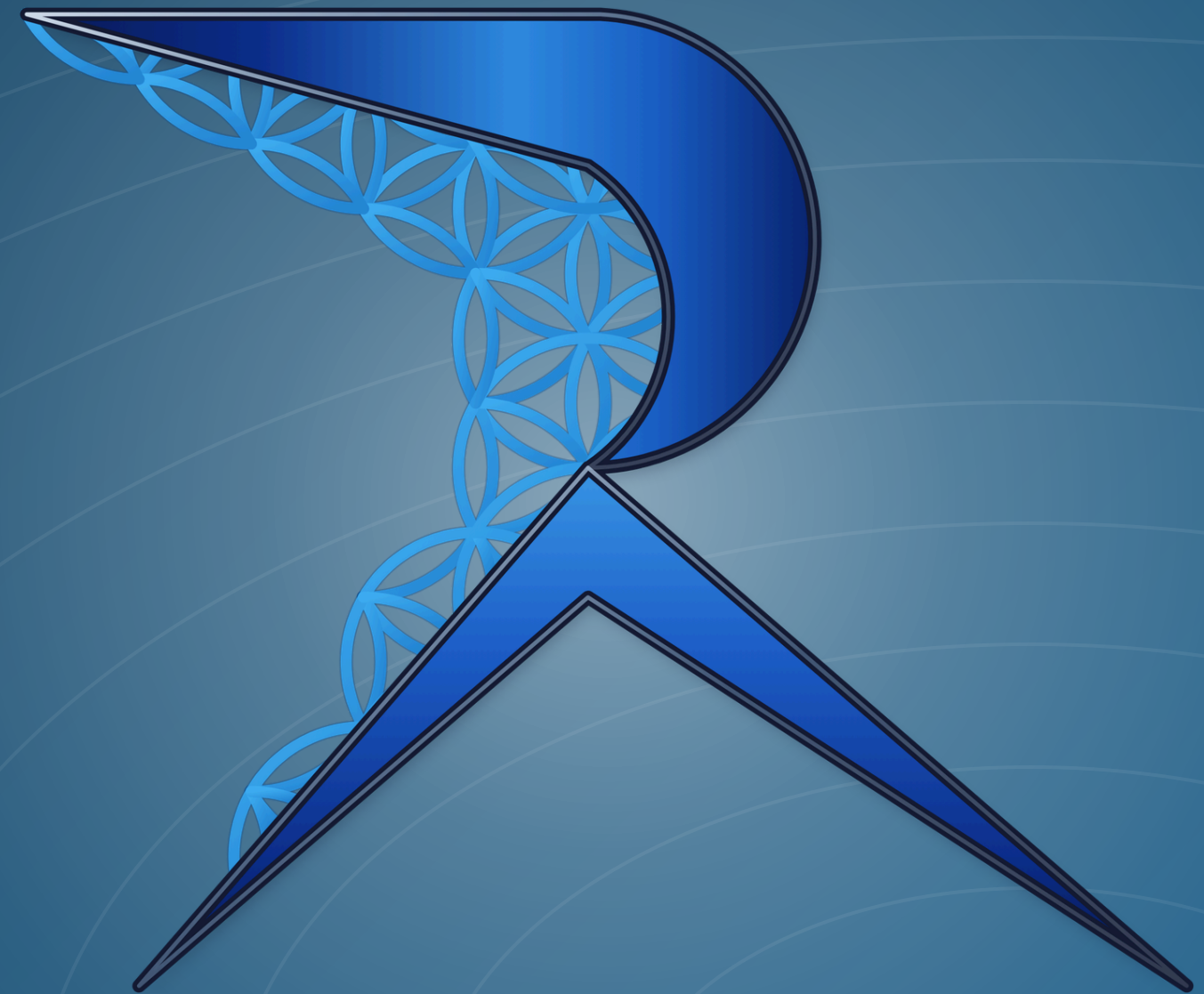
Ion Exchange Membrane

Electrolysis

for Acid Regeneration and Selective
Metal Recovery

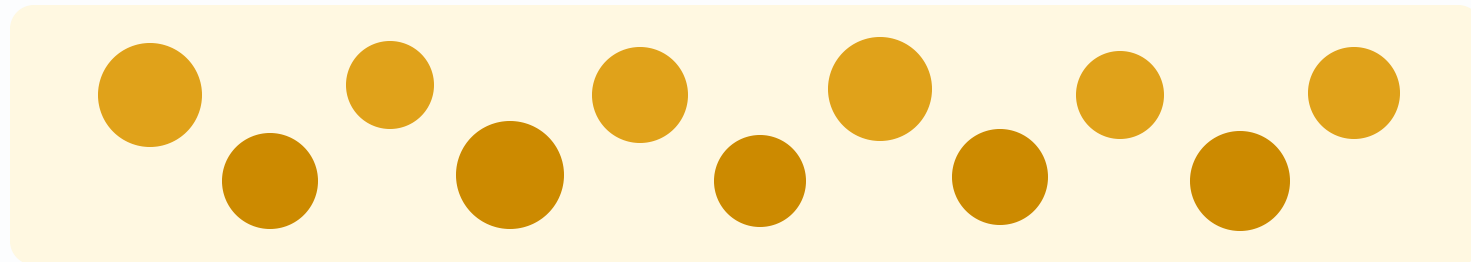
Robert Karas, Founder, Rowow LLC

S.E.M Technology (Salt Electro Mining) · rowow.net



RESIN OR MEMBRANE?

Same chemistry, used **two different ways**

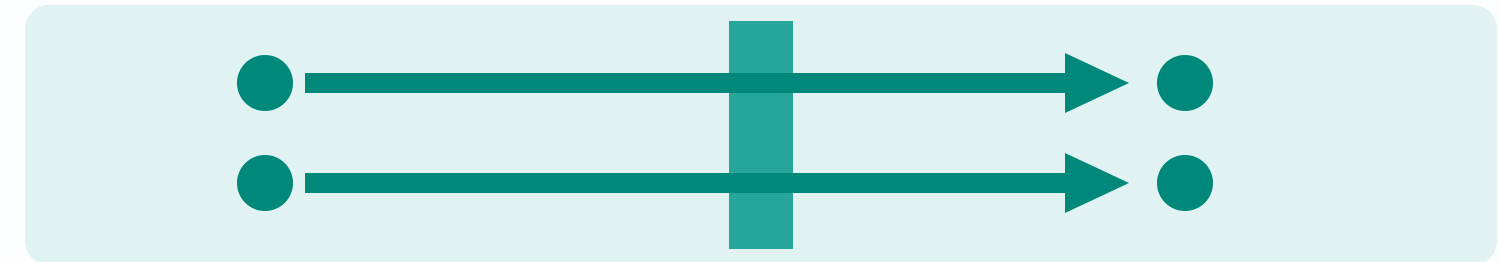


Ion exchange resin

Form: loose beads in a column or tank.

Job: trades ions. A softener takes calcium out of water and gives sodium back.

Runs in batches: it fills up, then has to be regenerated with brine or acid.



Ion exchange membrane

Form: a nonporous solid film that keeps two liquids apart.

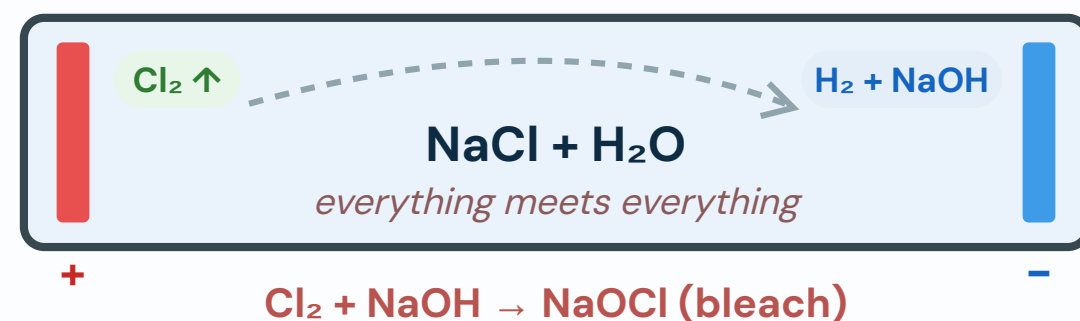
Job: passes ions through. One charge crosses, the opposite charge is held back.

Runs continuously: driven by current or a concentration difference, it never fills up.

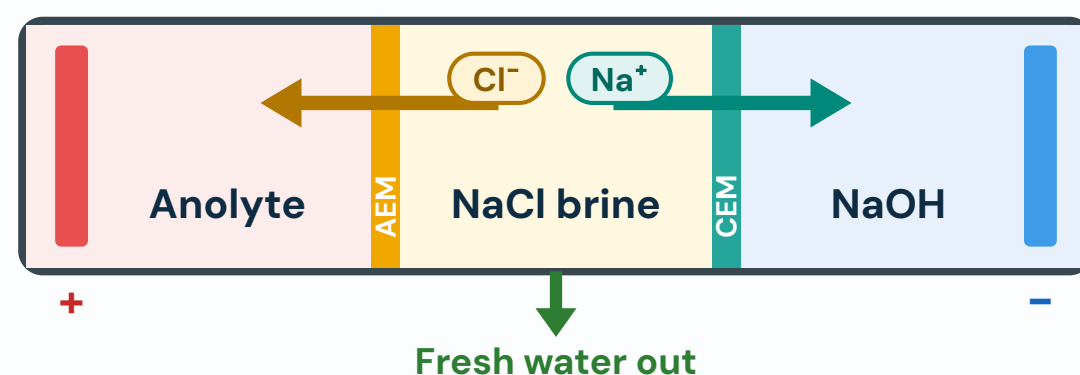
WHAT A MEMBRANE DOES

Membranes let electricity choose **which ions move**

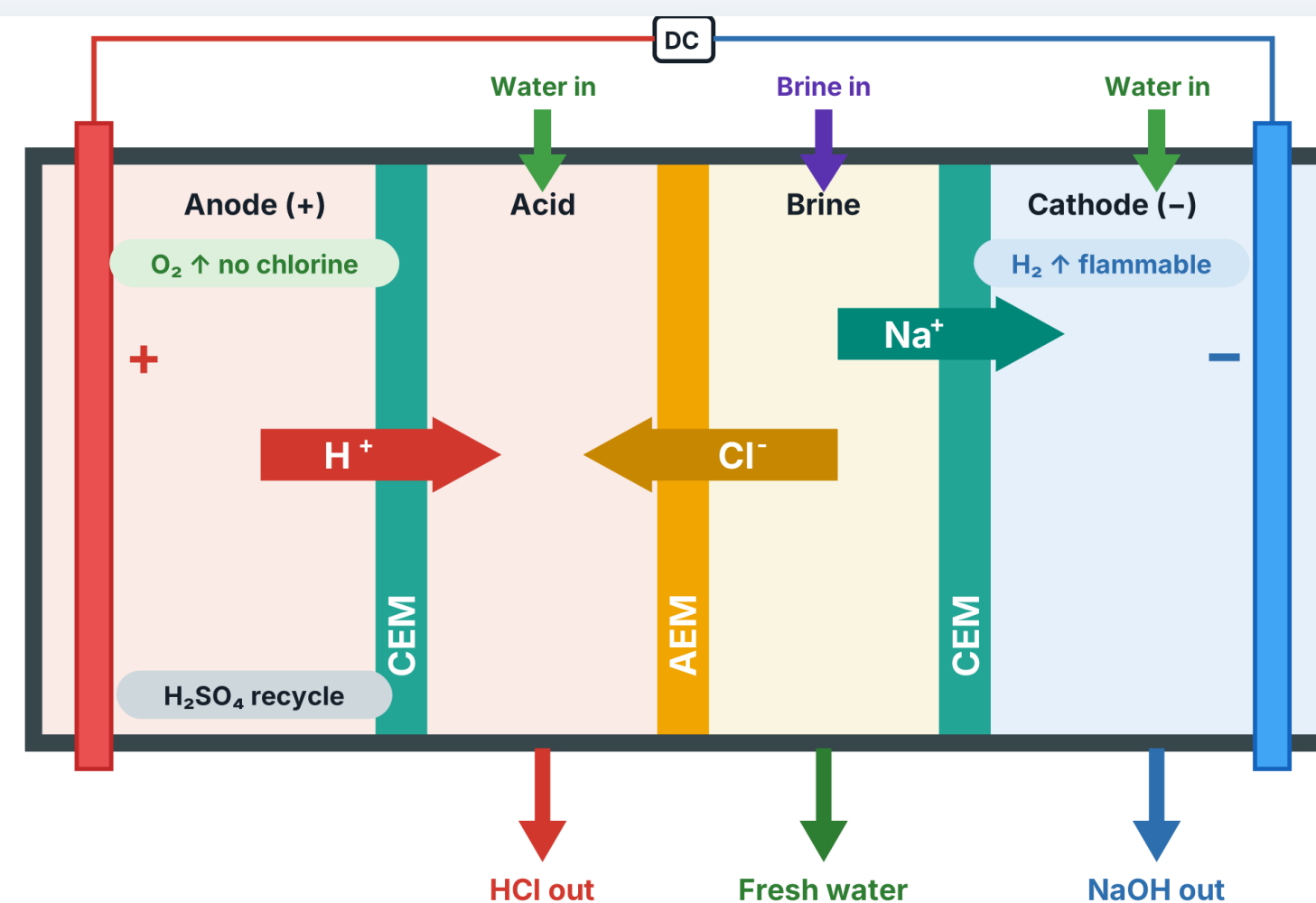
1 • No membrane: direct electrolysis in brine



2 • Two membranes, three chambers



3 • Three membranes: the anode gets its own acid loop



A **cation membrane (CEM)** passes positive ions; an **anion membrane (AEM)** passes negative ions. **No reagent is added, only electricity. The membrane order decides the products.**

THE FUNDAMENTALS

Every step in a phosphate plant **moves ions**

Make acid

Burn sulfur, absorb it as sulfuric acid.

Dissolve

Acid attacks the rock. Phosphate goes into solution, calcium leaves as gypsum.

Separate

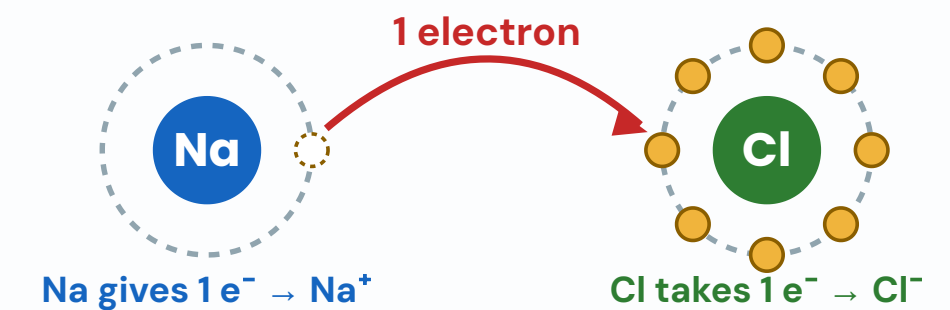
Keep the ions you sell, remove iron, aluminum, magnesium and fluoride.

Neutralize

Lime and pond water absorb what is left.

Industries move ions around with reagents and heat, producing byproducts.
All of chemistry comes down to atoms and their electrons.
Your body runs on membranes, from neurons to mitochondria.
Nature figured this out over a billion years before we did.
Half of chemistry is cleaning up the mess you just created.

Two atoms and their electrons



THE FUNDAMENTALS

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MEMBRANE CELL

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MEMBRANE CELL

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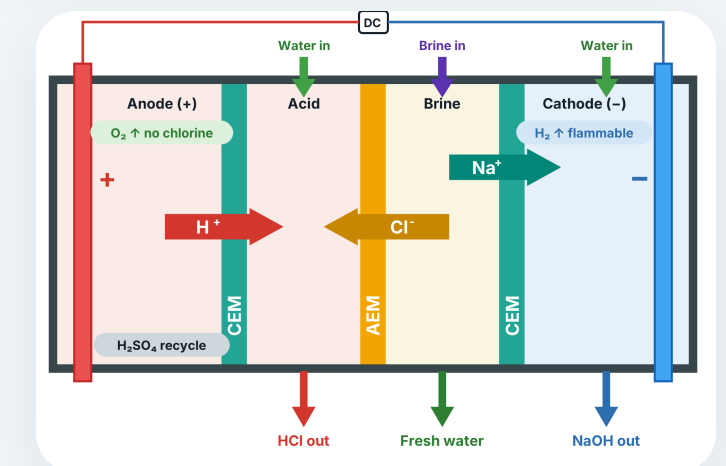
Keep the ions you sell, remove iron, aluminum, magnesium and fluoride.

MEMBRANE CELL

Neutralize

Lime and pond water absorb what is left.

In a membrane electrolysis cell these three are one step: the anode makes acid, the membrane separates, the cathode neutralizes.



PROVEN ELSEWHERE

Industry already runs membranes **at large scale**

Chlor-alkali

Brine and electricity make chlorine, caustic soda and hydrogen. A cation membrane keeps them apart. Over 50 million tonnes of chlorine a year.¹

Clean energy

Fuel cells and hydrogen electrolyzers run on a proton exchange membrane. Flow batteries use one to keep their two electrolytes apart.

Acid recovery

Diffusion dialysis across an anion membrane recovers free acid from spent pickling and metal finishing baths, with no current at all.²

Mining and phosphate mostly do not use them. The next slide is the reason.

THE BARRIER

Price and handling **keep membranes out of mining**

\$229 to \$242^{1,2}

per sq ft, retail commercial cation membrane, two US retailers, August 2026

33%³

of capital cost was membranes in a modeled mine water plant

39%³

of its operating cost was replacing them

Acid and oxidizers

Datasheets often stop at pH 1 or exclude strong oxidizers.

Fouling

Organics and fines foul the surface, and gypsum scales it in mineral liquors.

Sealing

Sheets are sealed by complex clamping between gaskets in a machined stack, which adds assembly time and cost.

Fragile

Homogeneous films a few tenths of a millimeter thick tear, crease, and swell.

SOURCES [1] MTI Corporation, \$229.16 per sq ft [2] Fuel Cell Store, \$241.55 per sq ft, both August 2026 [3] Roa, Lopez and Cortina, 2025, modeled mine water plant, three year membrane life assumed

OUR MEMBRANE

We mix it from water softener resin and PVC cement in under a minute

1 · Grind resin



2 · Mix in PVC cement



3 · Cast, brush or spray



4 · Sit

Bonds where cast

The binder is PVC cement, so the membrane welds straight into a PVC frame. No gasket between membrane and frame.

Almost any surface

Cast on fiberglass cloth, brushed into a frame window or sprayed as a thin film, in any shape or size.

Thickness is a choice

Thin for lower resistance, or thick and fiberglass backed for a sheet that takes handling.

Made where used

Commercially available ingredients from a hardware store. No clean room, no specialty sourcing, no import.

Under \$1 per sq ft¹

160 microns, from our cost model. Thicker hand-cast sheets cost more.

About a year²

in service at pH 0 with chlorine present, with no membrane failure observed so far.

WHY IT IS OPEN SOURCE

We published the recipe so **anyone can make the membrane** under our pending open source charter

Open hardware

Recipe, cell designs and build files under CERN-OHL-S v2, a copyleft license with a royalty free patent grant.

Replicated

Independent builders made it from the published recipe and tested it on camera.

Testable

Any plant lab can cast a coupon and run it in its own liquor before talking to anyone.

NightHawkInLight built and used the membranes: youtube.com/watch?v=eq7fR9ISuCw

PushingButtons replicated and tested the cation membrane: youtube.com/watch?v=-_kMtNR8-Ck

Neptunium ran an independent ICP analysis for us; our conversation on assays: youtube.com/watch?v=tD6LT8gqHYQ

MEMBRANE DATA

Our characterization paper publishes in the next **one to two months**



It will report, for our cation membrane and a commercial membrane tested side by side in the same cell:

Areal resistance

Ohm square centimeters, measured by impedance in a four electrode cell.

Selectivity

Permselectivity, and a dye crossover test of what leaks through.

Durability

A membrane retired from long acid and chlorine service, against a new one.

Ion exchange capacity

Milliequivalents per gram, by titration.

Water uptake and swelling

How much the membrane takes up and how much it changes size.

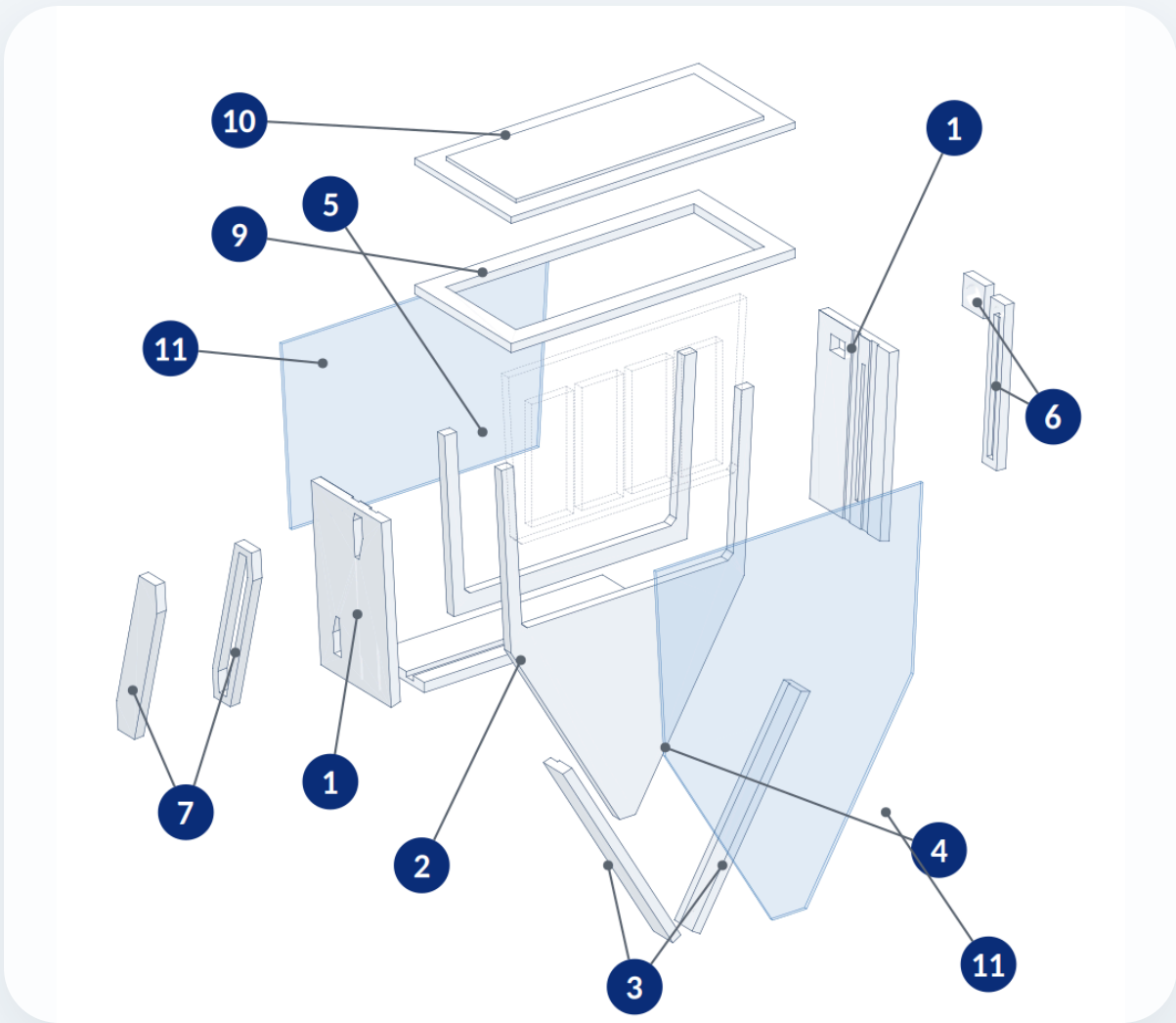
Current limits

The limiting current density, from current and voltage sweeps: how hard the membrane can be driven.

Thank you to Admiral Instruments for donating the Squidstat Plus potentiostat that makes these measurements possible. Methods and data will be published openly with the paper.

THE REST OF THE STACK

We are cutting cost across **the whole cell**, not only the membrane



Hot-swappable membranes

Change or upgrade a membrane without taking the cell apart.

Cheaper electrodes

Low cost electrode materials in place of precious metal coatings.

Better connections

A low cost way to wire electrodes that holds up in acid service.

Modular cell

One cell body runs two or three chambers, built in house.

Patent pending, and pending release under our open source charter.

WHY IT MATTERS TO PHOSPHATE

Florida's phosphate waste still holds a lot of value

About 39%

of the P₂O₅ mined never reaches the acid. Most sits in the clay settling areas.^{1,2}

About 2.5 to 4 million t of P₂O₅ a year

1 billion tons

of phosphogypsum waste stacked in Florida, growing about 30 million tons a year.¹

\$25 to \$35 billion to keep for life, plus \$0.75 to \$1 billion a year⁹

9,000 t a year

of rare earths go to Florida clay and gypsum.³ The US imports about 6,800 t a year straight from China (2021 to 2024 average).⁴

\$70 to \$180 million a year at US rare earth import prices⁴

\$840 to \$1,100

of P₂O₅ left in the waste for every ton of P₂O₅ sold, valued at 2026 phosphoric acid prices.^{1,2,8}

\$3 to \$6.5 billion a year at acid prices, about \$1 billion as rock^{4,8}

4 to 5%

of the fluorine mined in US phosphate is recovered.^{4,7} The US imports all its fluorspar, a key critical mineral.⁴

\$640 to \$740 million a year as fluorspar, about 4 times US imports⁴

11 to 35 pCi/g

radium-226 in the gypsum stacks.⁵ The agricultural use limit is 10 picocuries per gram.⁶

SOURCES [1] FIPR [2] US DOE, phosphate matrix composition [3] DOE NETL project DE-FE0032123 [4] USGS Mineral Commodity Summaries 2026 [5] US EPA, TENORM: fertilizer and fertilizer production wastes [6] 40 CFR 61.204 [7] US EPA AP-42, section 8.9 [8] Argus, India phosphoric acid contract prices, 2026 [9] IFA 2016, phosphogypsum disposal. Percentages, tonnages and dollar totals are our arithmetic from these.

THE SULFUR PROBLEM

Phosphate depends on a by-product **nobody here controls**

\$705

per long ton, Tampa sulfur, Q3 2026. A record.¹ Under \$100 a ton in early 2024.²

Over 80%

of the world's sulfur is a byproduct from refining oil and gas. Less refining means less sulfur.³

Nearly half

of seaborne sulfur normally ships from the Middle East, through Hormuz.⁴

In 2026 China banned sulfuric acid exports⁴ and Florida phosphate output was cut back.⁵ Hydrochloric acid routes to phosphoric acid already run commercially, and making that acid from salt and electricity has been piloted on sewage sludge ash.⁶

Sources [1] Fertilizer Daily, July 15 2026 [2] farmdoc daily, August 2026 [3] Maslin and Day, Geographical Journal, 2022 [4] S&P Global, May 7 2026 [5] Mosaic Q2 2026 earnings call [6] IMI and Ecophos processes; TU Freiberg PARFORCE pilot, EP3266742B1

ENERGY AND COST, FROM THE LITERATURE

Regenerated electrolyzed acid now beats burning sulfur

Acid supply only, per ton of P2O5. Rock, conversion and the change to a hydrochloric acid process are not included. Power at 8.5 cents per kWh.⁵

Per ton of P2O5	Sulfur bought, 2024 price	Sulfur bought, Q3 2026 price	Regenerated in a membrane stack
Acid needed	2.3 to 2.7 tons sulfuric, from 0.75 to 0.87 tons sulfur ³	2.3 to 2.7 tons sulfuric, from 0.75 to 0.87 tons sulfur	None bought: 1.7 to 2.0 tons hydrochloric circulates
Electricity	Exports power as steam	Exports power as steam	1,800 to 5,400 kWh to regenerate it ⁴
Acid cost	\$35 to \$87 of sulfur ¹	\$520 to \$600 of sulfur ²	\$150 to \$460 of power ⁵
Calcium leaves as	About 5 tons of phosphogypsum, \$125 to \$180 to dispose ⁷	About 5 tons of phosphogypsum, \$125 to \$180 to dispose ⁷	About 3 tons of calcium chloride, a possible product (below)
P2O5 left in waste	\$840 to \$1,100 of P2O5 (page 12)	\$840 to \$1,100 of P2O5 (page 12)	Leached clay: 93 to 98% extracted ⁸

Where the calcium chloride could go

Split it into acid and lime

Returns the acid and makes lime for cement, steel and water treatment.⁶

Lock up carbon dioxide

Lime from the split absorbs CO2 as calcium carbonate, a filler for paper, plastics and paint.

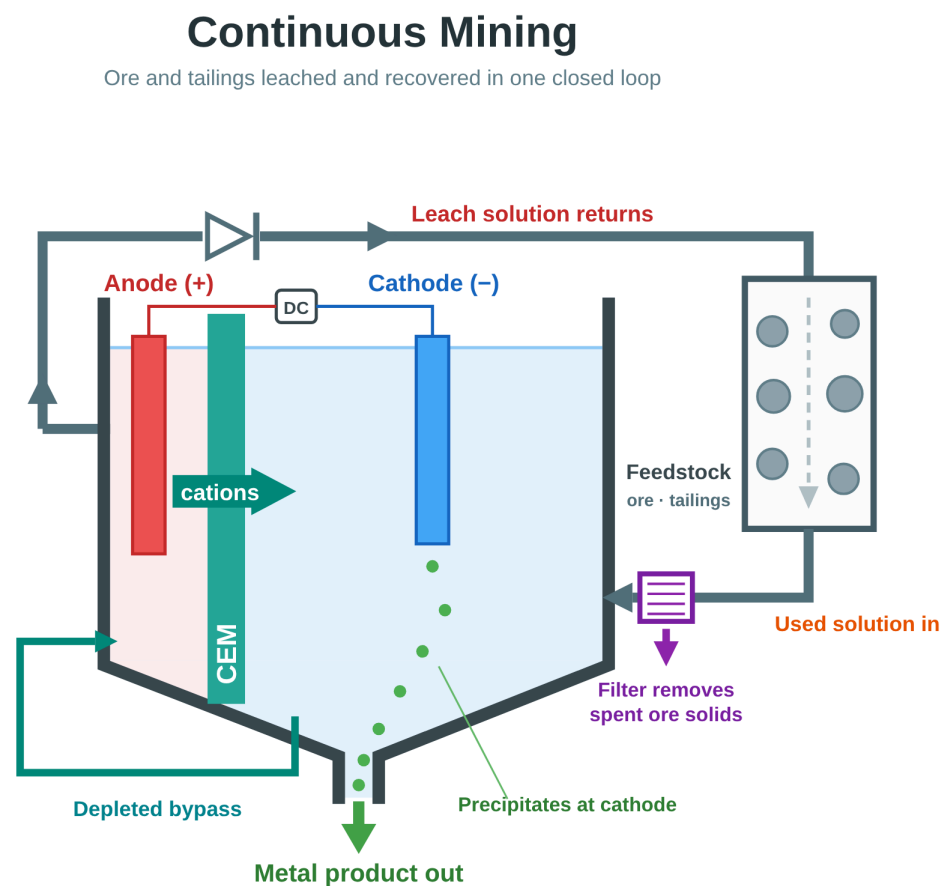
Drilling and concrete

Drilling fluids and concrete set accelerators, as side outlets.

Sources [1] USGS MCS 2025, sulfur; farmdoc daily, Aug 2026 [2] Fertilizer Daily, July 15 2026 (\$705 per long ton) [3] farmdoc daily, Aug 2026 (0.4 t sulfur per t DAP) [4] Virruso et al., Desalination 583, 2024; PMC9657526 [5] EIA, Florida industrial power, 2024 [6] USGS MCS 2026, lime [7] IFA 2016, phosphogypsum disposal US\$25 to \$35 per t [8] Stanczyk, US Bureau of Mines RI 6844, 1966: Florida slime, 90 °C, sulfuric, hydrochloric or nitric acid, bench scale. Acid tonnages, energy and costs are our arithmetic from these.

THE CLOSED LOOP

Currently used in the Continuous Mining Unit (CMU)



1 • Leach

Dilute hydrochloric acid and a chlorine based oxidizer dissolve the metals from ore, tailings or waste.

2 • Recover

The metal rich liquor flows through a membrane divided cell. Dissolved metals plate out at the cathode as a powder or deposit.

3 • Regenerate

At the anode, brine and electricity remake the acid and oxidizer, so the same solution goes back to the ore instead of being bought again.

4 • What it has done

Precious metals: Au, Pt, Pd, Rh and Ir confirmed by assay.¹

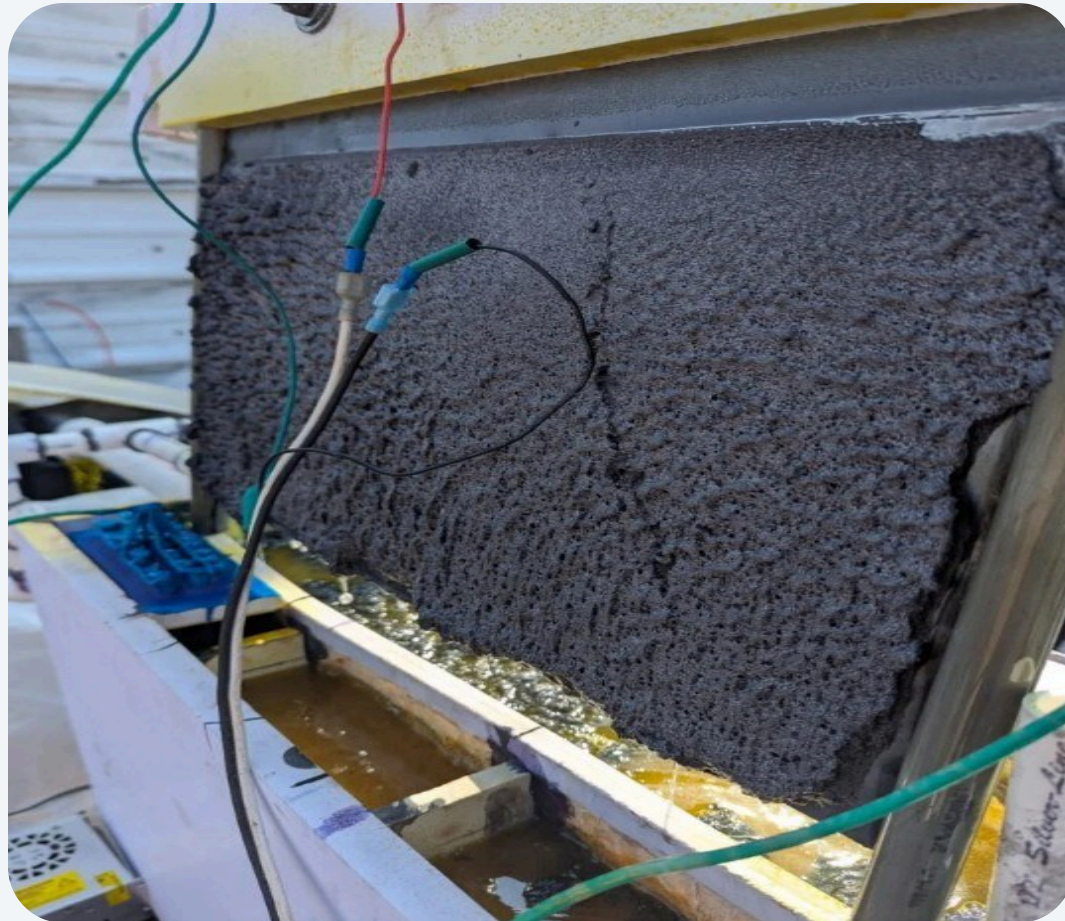
Detected: 53 of 60 US critical minerals in solution.²

Mine waste: reduced 255 gal, under 33 kWh, \$3 worth of electricity.²

SOURCES [1] Third-party ICP-MS on earlier concentrate (results by email, available on request); XRF, third-party and in house [2] Rowow bench runs. 53 of 60 were detected in solution or collected concentrate, not individually recovered.

WHAT COMES OUT

Metals leave the cell as a deposit at the cathode



Metal deposit built up on a cathode.



A running cell: leach liquor and the deposit forming.



Recovered rare earth oxide concentrate from a continuous mining unit run, before refining.

SELECTIVE SEPARATION

The mixed concentrate can be split **by voltage, pH, membrane or solvent**

Voltage control

Each metal plates at its own potential. Hold the cathode and the more noble metal comes out first: copper (+0.34 V) before nickel (−0.26 V) and zinc (−0.76 V).¹

Ionic solvents

Move the ions into an ionic liquid and different metals stay dissolved. One ionic liquid split neodymium, dysprosium and cobalt from iron in magnet scrap.⁴

pH steps

Raise the pH in steps and metals drop out one at a time. Iron, aluminum, copper and zinc have been recovered in sequence from acid mine drainage.²

Continuous Refining Unit

Our same membrane cell, run with nitric or acetic acid, designed to strip base metals from doré and mixed concentrates and leave the precious metals behind.

Selective membranes

Valence selective membranes pass single charge ions and hold back double charge ions, so the membrane itself does part of the sorting.³

Our anion membrane

On the bench it passes chloride and holds back sulfate. In a sulfate rich phosphate stream, that would keep sulfate on its side.

¹ Standard reduction potentials vs SHE, CRC Handbook of Chemistry and Physics. ² Park et al., Environ. Sci. Pollut. Res. 22 (2015) 3013. ³ Fan, Huang and Yip, Front. Environ. Sci. Eng. 17 (2023) 25. ⁴ Dupont and Binnemans, Green Chem. (2015), doi 10.1039/c5gc00155b; review: Binnemans and Jones, J. Sustain. Metall. (2017), doi 10.1007/s40831-017-0128-2.

WHAT COMES NEXT

We have only scratched the surface

Everything in this talk came from a small lab running on product sales and donations, and our resources set the pace. Next, we are **publishing the membrane paper, scaling up membrane production and testing, and building a portable, fully closed loop pilot plant** that carries ore all the way through to separated elements.

WAYS TO WORK WITH US

Your own test cell

Buy an electrolysis cell and membranes from rowow.net and run your own liquor in house.

Paid test run

We run your material and report the results with their basis, good or bad.

Consultation

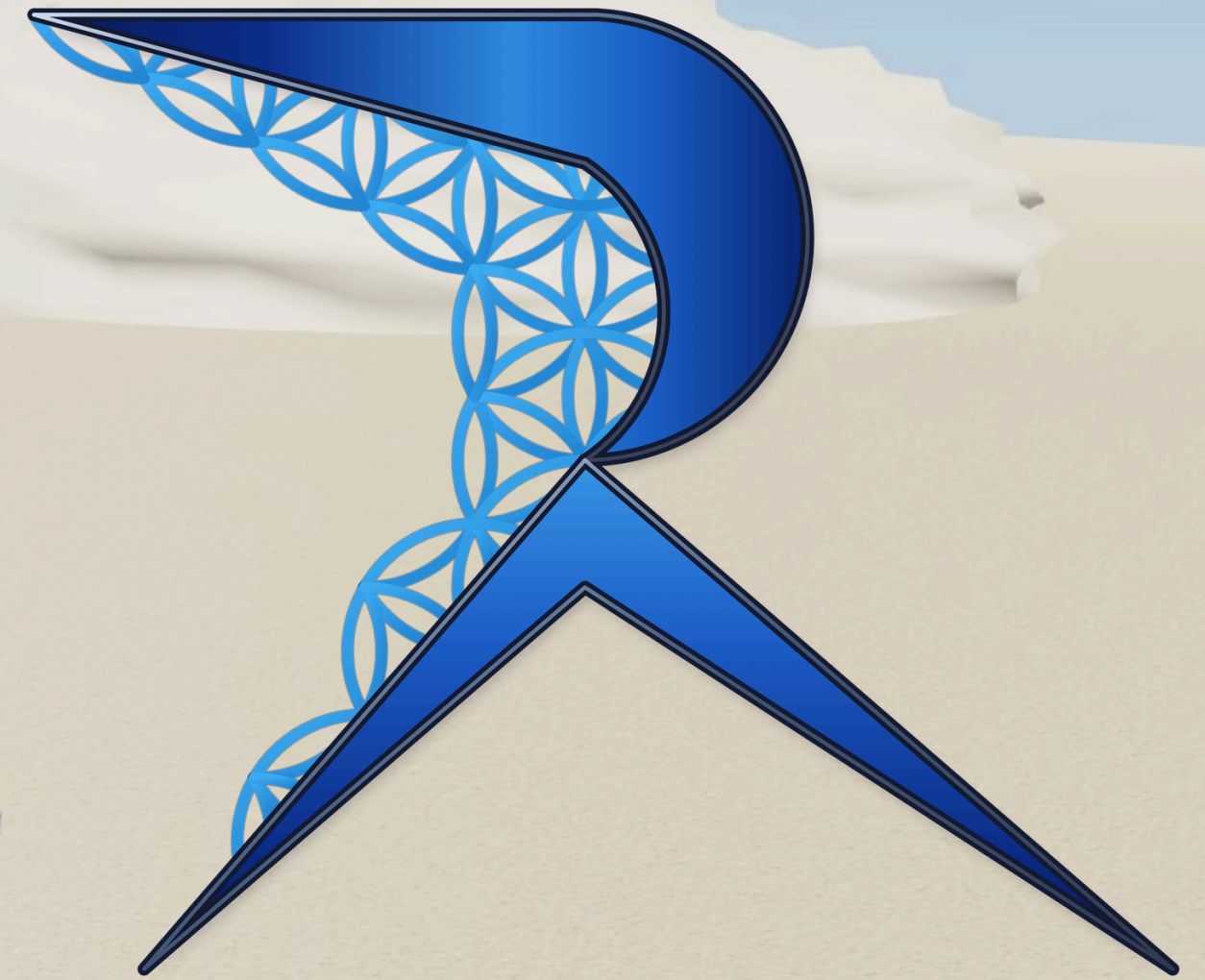
Advice on membrane and electrochemical options for your streams and plant.

Build on the recipe

Cast a coupon, test it in your liquor and publish with us. University and lab partners welcome, toward peer reviewed proof.

info@rowow.net rowow.net · youtube.com/@Rowow

Thank you. Questions?



Background: concept model of the planned trailer pilot, not a built machine

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