OAK RIDGE National Laboratory

MAY 21, 2026 | OAK RIDGE, TENNESSEE

Critical Mineral Recovery Technologies from Oak Ridge National Laboratory

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U.S. DEPARTMENT of ENERGY

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Parans Paranthaman,
Corporate Fellow, ORNL
Chemical Sciences
Division

OAK RIDGE
National Laboratory

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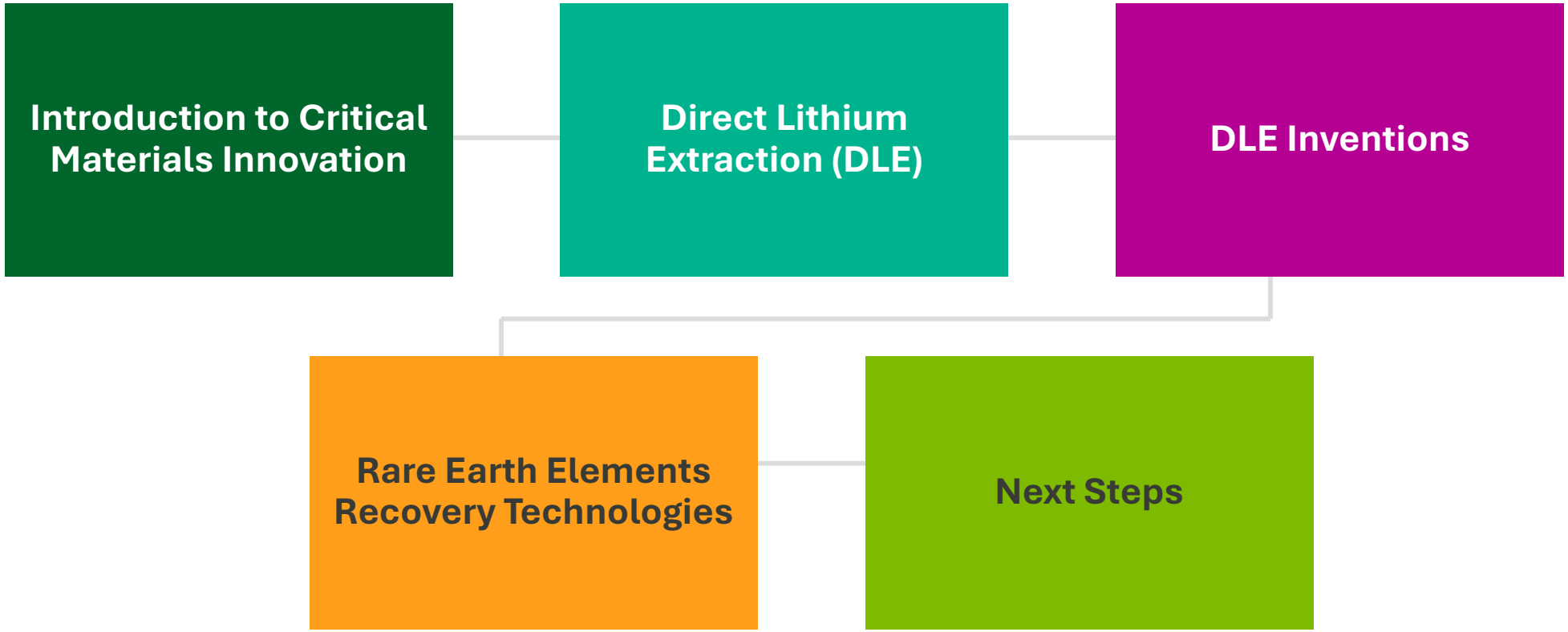
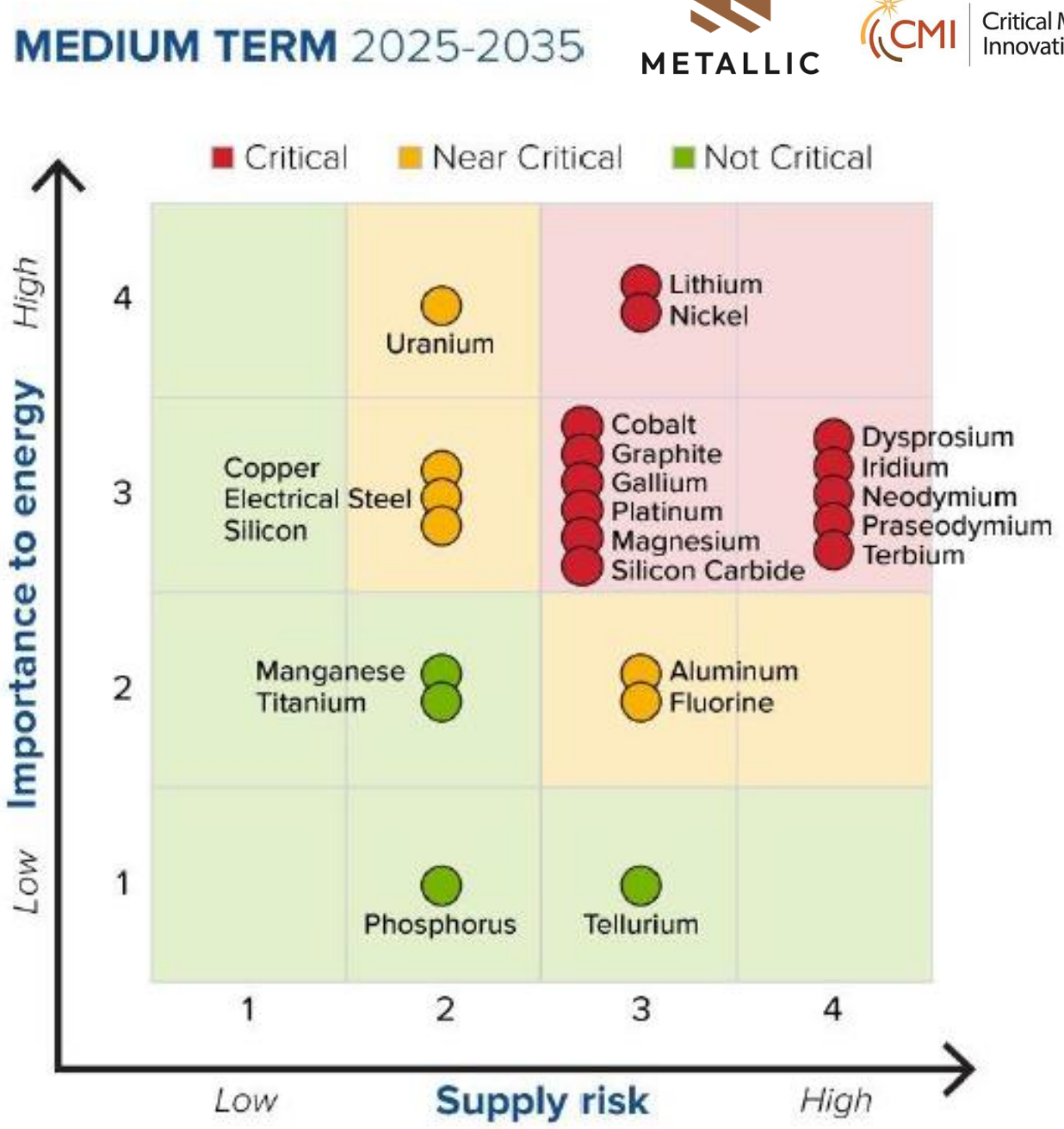


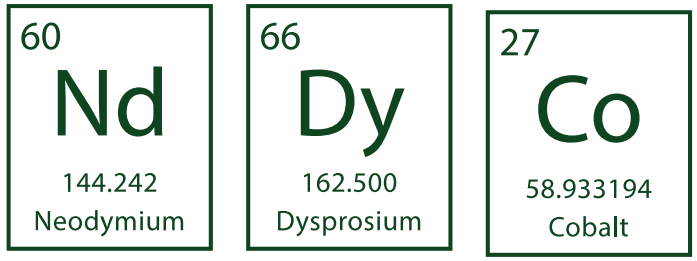
What are Critical Materials and Critical Minerals?

Magnets, batteries, Wide-Bandgap (WBG) semiconductors, platinum group metals

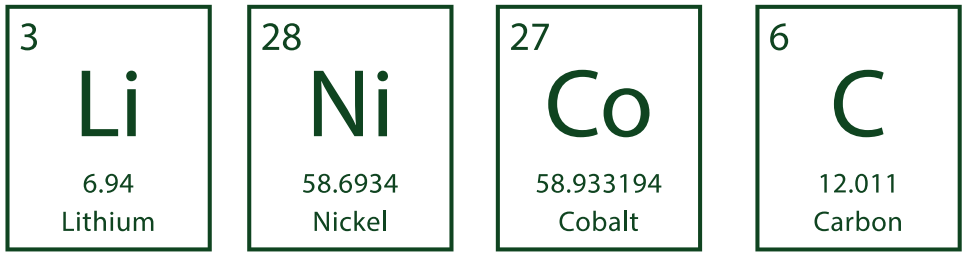


U.S. DOE Releases 2023 Critical Materials Assessment to Evaluate Supply Chain Security for Clean Energy Technologies, July 31, 2023

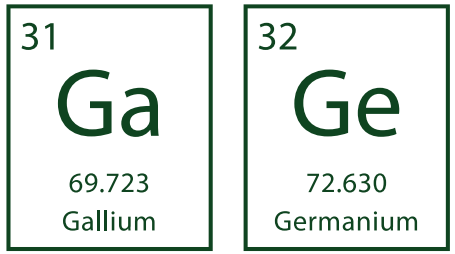
CMI projects focus on early-stage R&D (TRL 2-4)



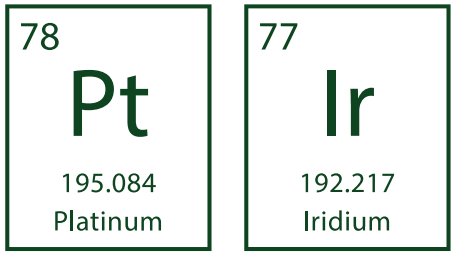
Rare Earth Permanent Magnets: Nd; Dy-Fe-B; Sm-Co



Lithium-ion Battery Electrode Materials



WBG Semiconductors



Platinum Group Metals

The Minerals to Materials Supply Chain Research Facility (METALLIC) builds upon existing DOE efforts to address the CMM challenges of today & the future

VISION

Accelerate CMM RD³

Expertise, facilities, and support for technology developers

Validate Emerging Technologies

Trusted partner for funding agencies, financiers, and licensees

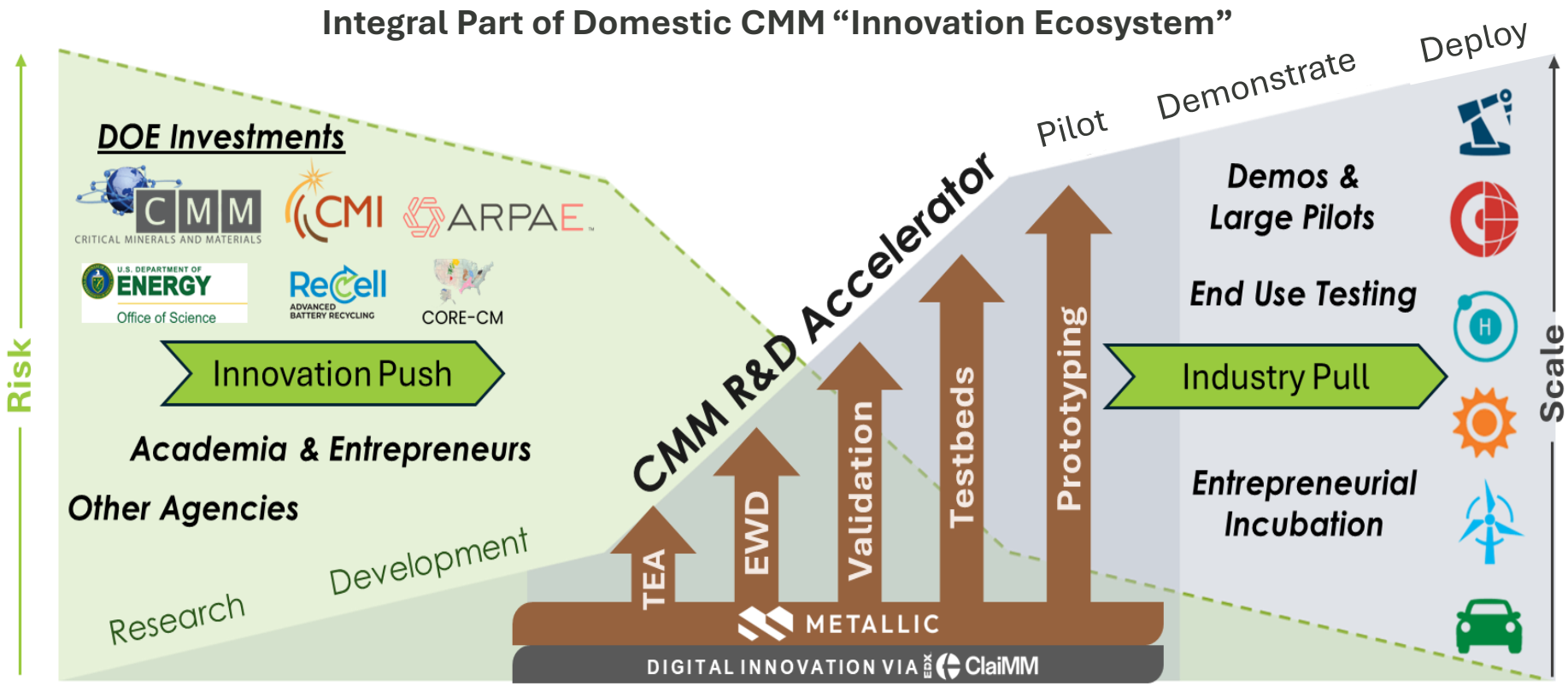
Action Oriented, Future Focused

Generate knowledge and "know how" to rapidly address future CMM challenges

OUTCOME

Foundational capability for the nation to address the CMM challenges of today and the future

METALLIC functions as a “one-stop shop” for faster and cheaper CMM technology maturation



NATIONAL ENERGY TECHNOLOGY LABORATORY

The Ames Laboratory

Argonne NATIONAL LABORATORY

BERKELEY LAB

INL Idaho National Laboratory

Pacific Northwest NATIONAL LABORATORY

Lawrence Livermore National Laboratory

National Laboratory of the Rockies

OAK RIDGE National Laboratory

Four Centers of Excellence

ENABLING ACTIVITIES

Centers Integrating Innovations Across the Supply Chain

AI & ML

TEA/LCA

Feedstock Beneficiation

Near-zero waste, minimally invasive feedstock production

Extractions and Separations

Optimal material processing methods and technologies reduce impact and maximize value

Refinery

Improved manufacturing methods for high-purity CM from domestic resources

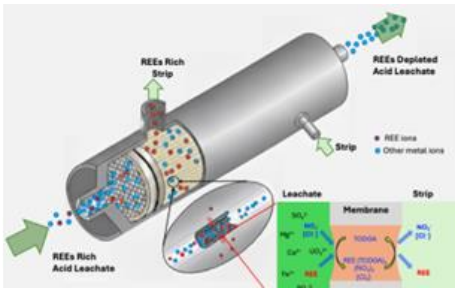
Alloy Development and Advanced Mfg.

CM-efficient, high-performing, low-impact substitutes & components

Process Modeling & Optimization

Secured Data Warehouse

ORE Lab



Membrane Solvent Extraction (MSX) Testbed

M-TEL

Pyrometallurgical Flagship

Solid Phase Processing for Advanced Alloy Production

“One-Stop Shop” to support domestic CMM innovation

METALLIC

METALLIC

Industry can access METALLIC to mature emerging technologies in less time and at less cost by

Single Point of Contact
Eliminates time spent trying to find the right expert and facility

Streamlined Agreements
Shortens time from first contact to starting work

Existing Equipment and Testbeds
Reduces procurement costs and avoids long lead times

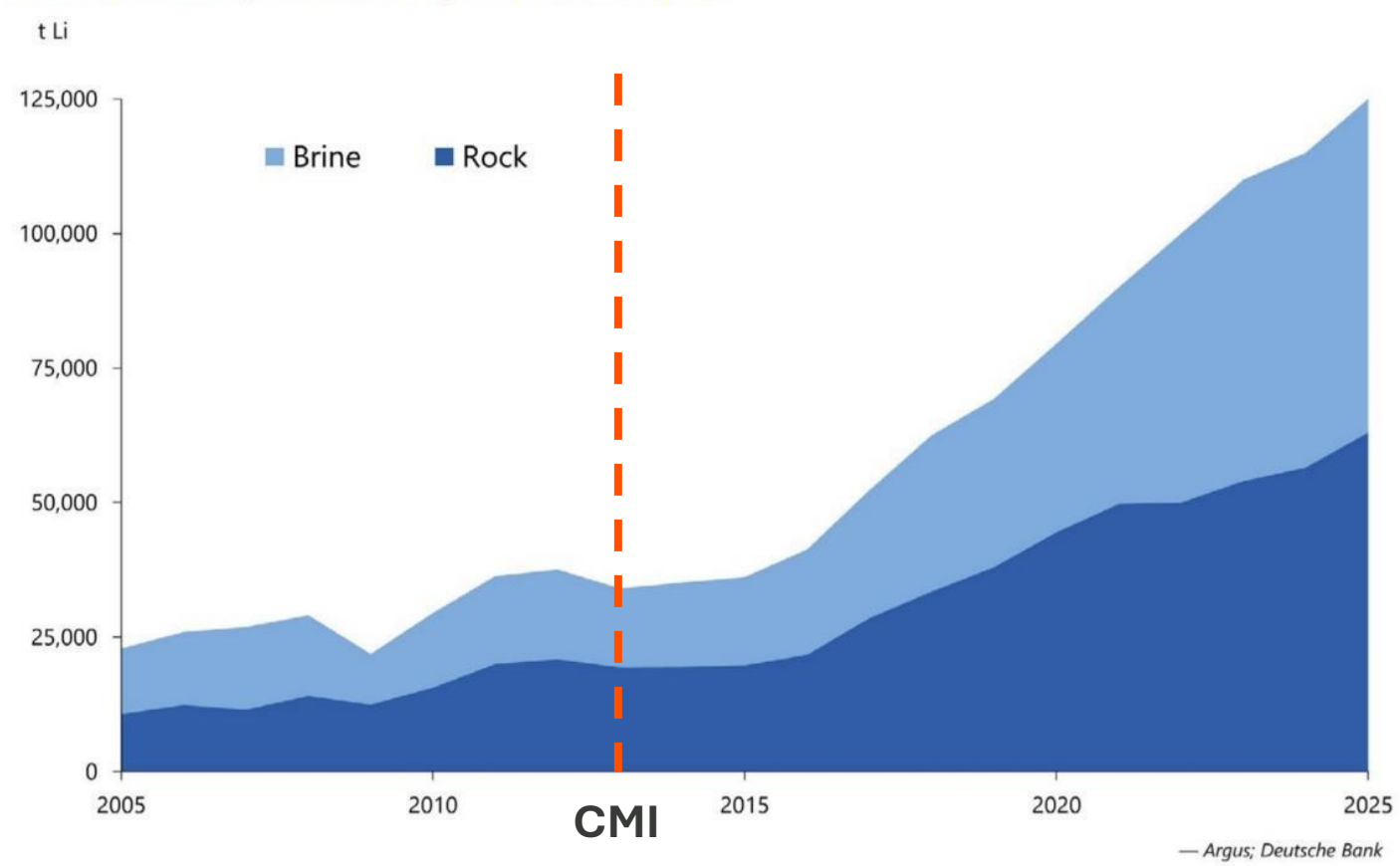
Analytical Support
Accelerates feedstock data collection

Dedicated, Trained Workforce
Reduces time required to hire and train staff

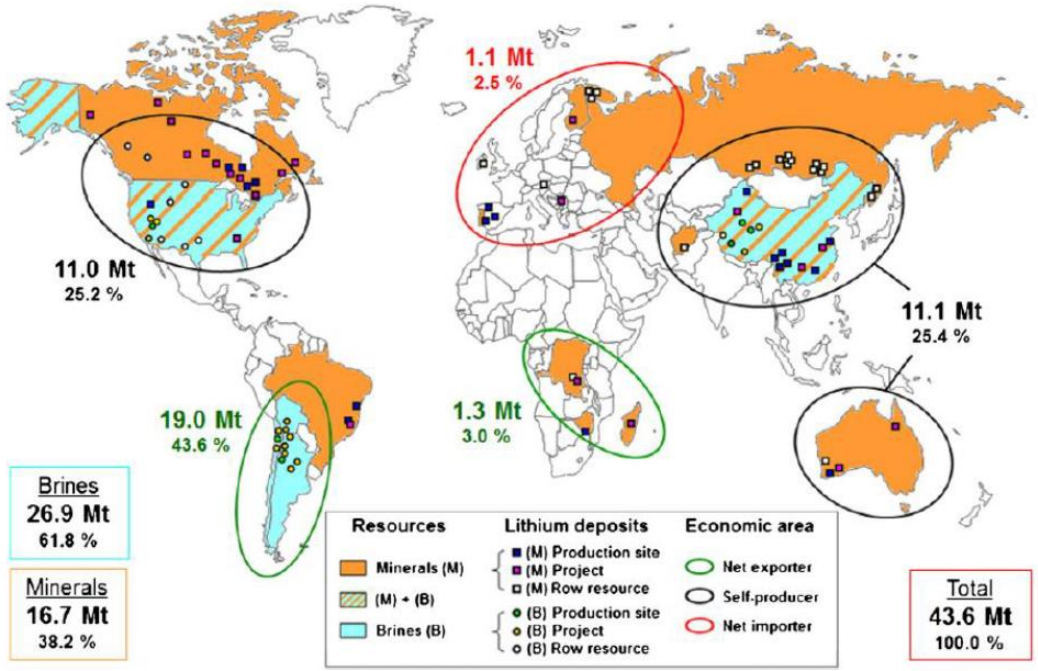
Direct Lithium Extraction

Brines play a major role in lithium production

Global lithium production by source

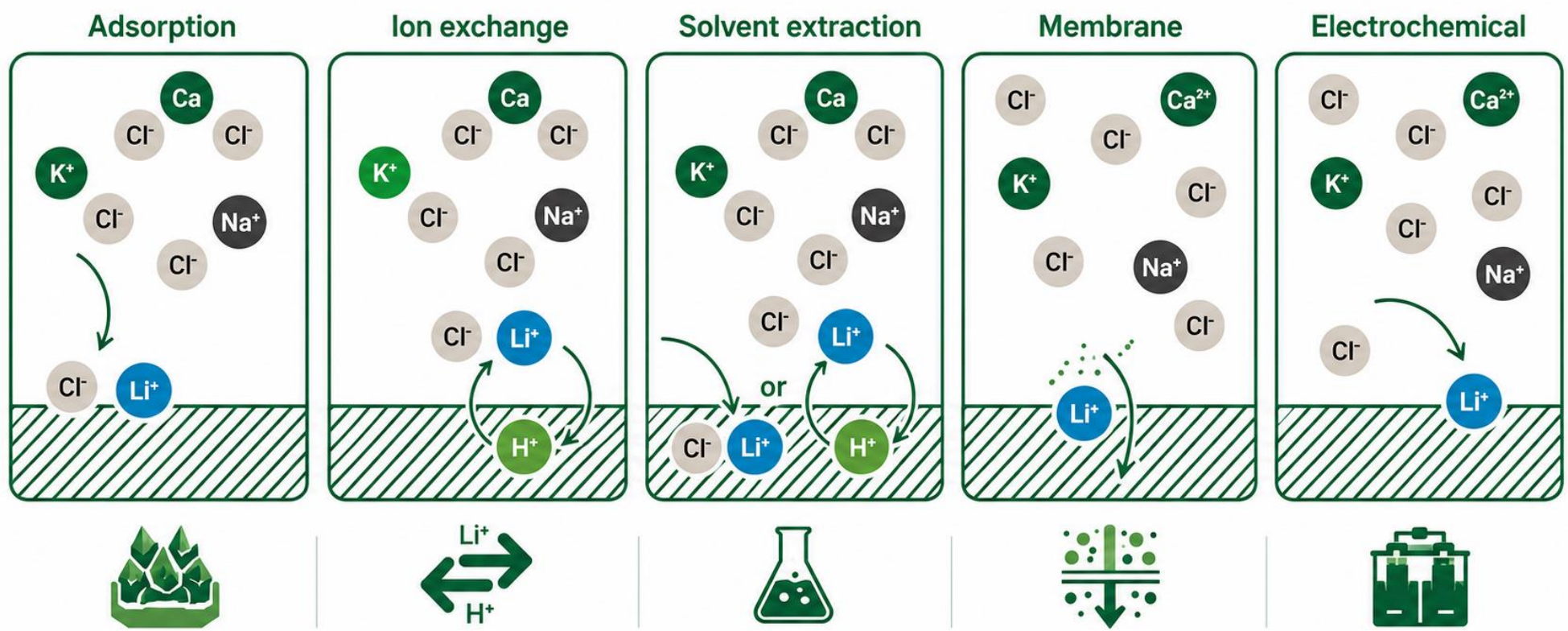


Global lithium resources



There are different kinds of Direct Lithium Extraction technologies

Adsorbents have been demonstrated at commercial scale



Direct Lithium Extraction (DLE) – High-Capacity Sorbents is a promising technology to extract lithium from brines, minerals, and batteries

Corporate Fellow
Parans Paranthaman
and Jayanthi Kumar

Direct Lithium Extraction addresses several challenges of other lithium recovery methods

Challenges addressed:

It can operate a wide range of pH and temperature conditions

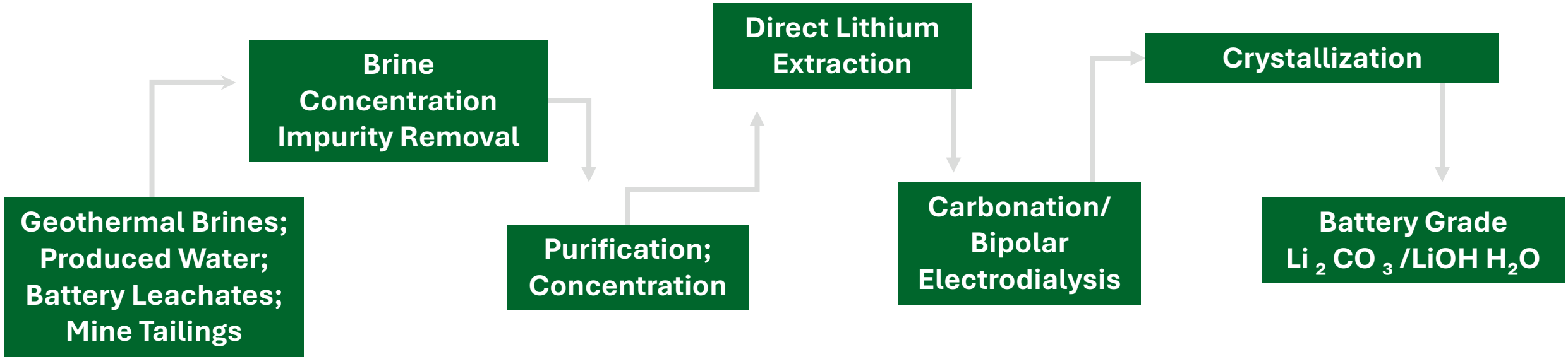
Only water is needed for the delithiation process

No need for acids and bases for the DLE

Lithium extraction process is quick compared to competing methods

In 2024, Element3 licensed and commercialized this technology

Flow chart demonstrating lithium extraction



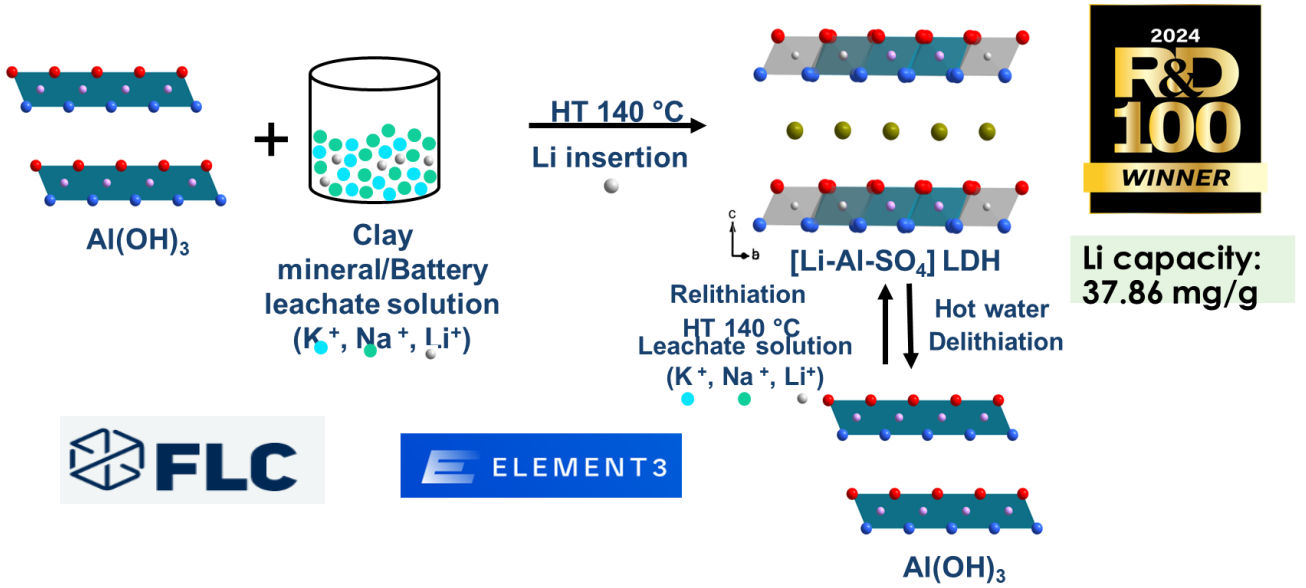

Lithiated Sorbent
H2O
Delithiation
Sorbent + Li+
DIRECT
LITHIUM
EXTRACTION
Na+, K+
Lithiation
Li+, Na+, K+
Li+
Sorbent

Lithium Extraction: Lithiation step followed by delithiation process

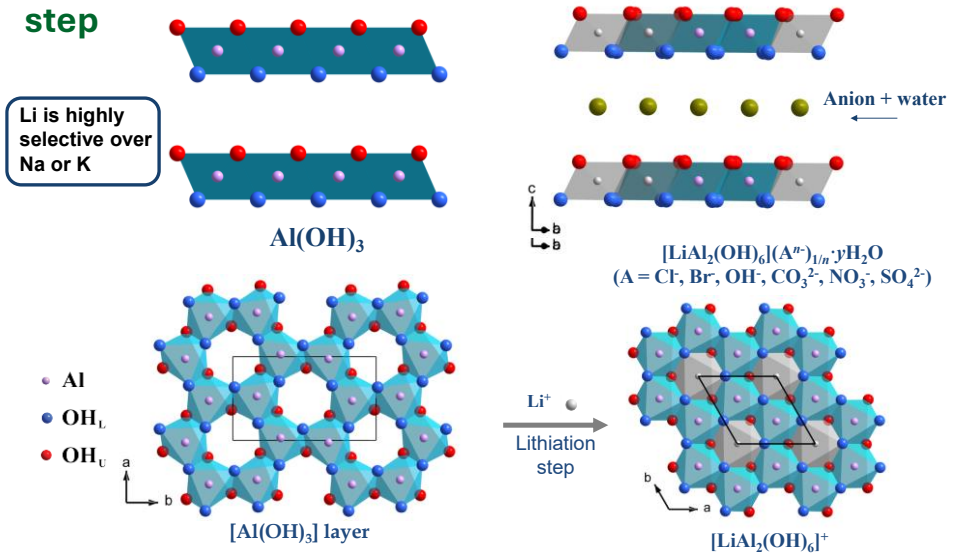
Aluminum hydroxide sorbents

Low-cost; earth abundant materials; commercially available

High capacity; recyclable; scalable



Lithium is selectively intercalated into $Al(OH)_3$ during the lithiation step



Key aspect of the technology

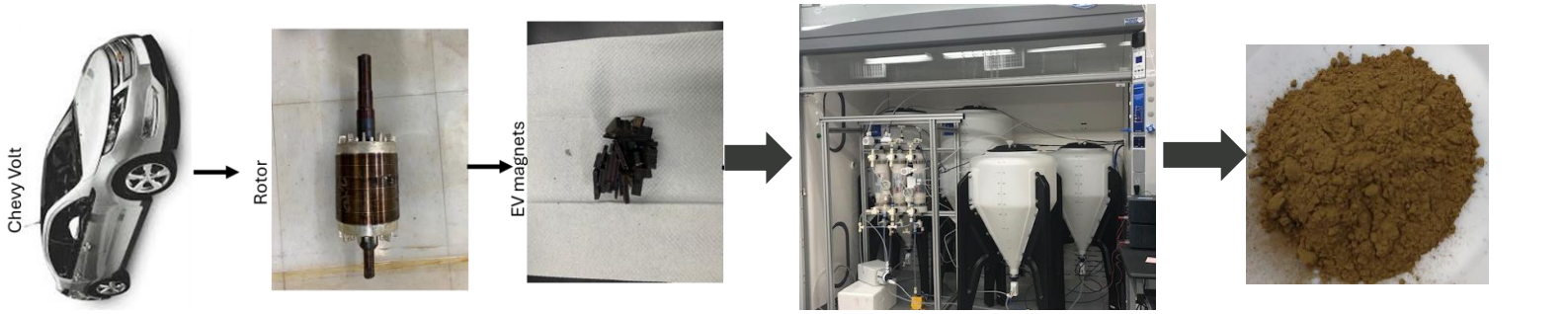
Integrated circular economy model for DLE: Minerals to Batteries using Aluminum Hydroxide sorbents

Life-cycle analysis predicts significant environmental advantage of this system compared to that of conventional evaporation-precipitation process.

In 2026, Element3 broke ground on a new lithium carbonate plant.

A sample of available technologies from ORNL

Critical Minerals Recovery using Membrane Solvent Extraction (MSX)



Recycling magnets

MSX at ORNL

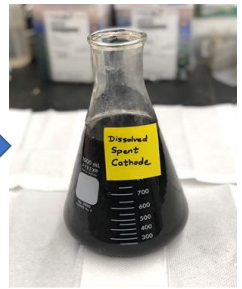
Rare Earth Oxides

MSX Facility at Momentum Technologies

Recycling batteries

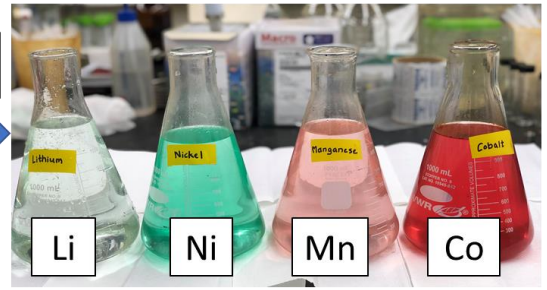
Spent Lithium-Ion Battery (LIB)

Spent LIB black mass

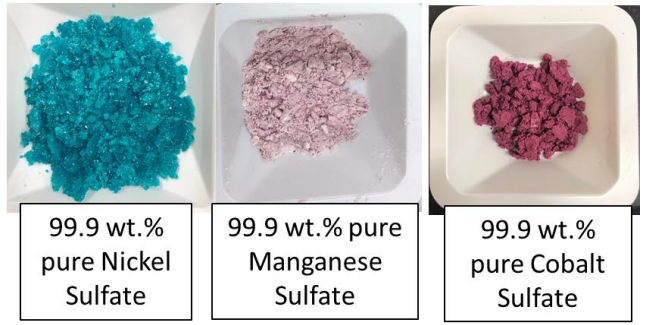


Black mass dissolved in acid

MSX



Recovered LIB sulfates



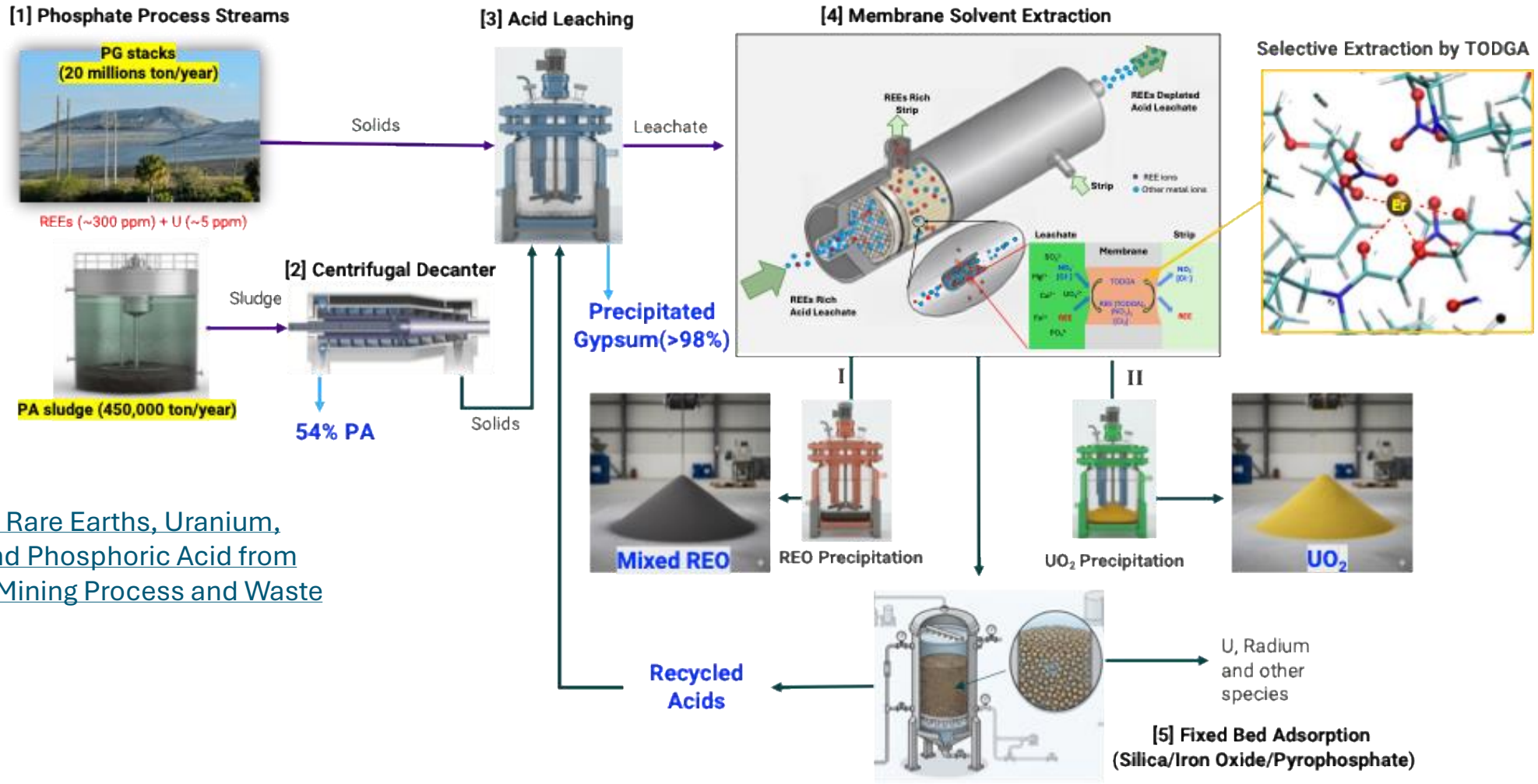
99.9 wt.% pure Nickel Sulfate

99.9 wt.% pure Manganese Sulfate

99.9 wt.% pure Cobalt Sulfate

Recovered metal sulfate powders

Rare Earth Elements and Uranium recovery from Phosphogypsum (PG) Phosphoric Acid (PA) sludge



[Recovery of Rare Earths, Uranium, Gypsum, and Phosphoric Acid from Phosphate Mining Process and Waste Streams]

Rare Earth Elements and Uranium recovery from Phosphoric Acid (PA) sludge (METALLIC Facility)

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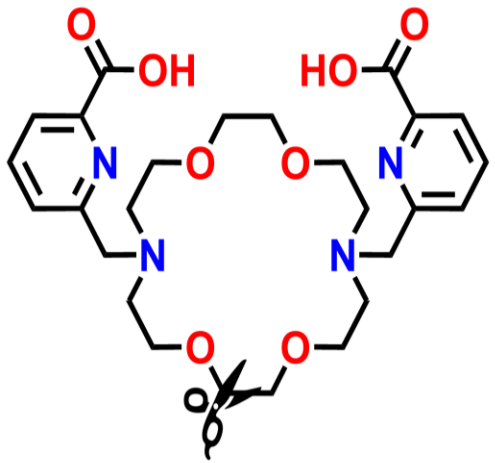
Novel Extractants for Rare Earth Chelation and Separation

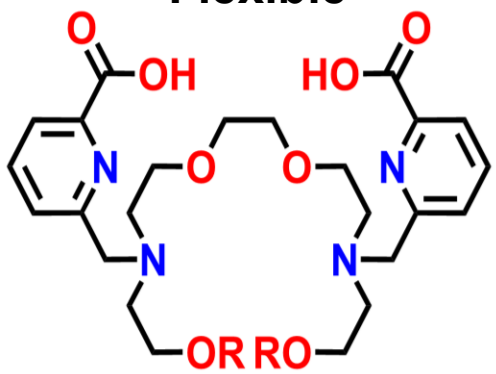
Rigid



macropa

Rigid ligand

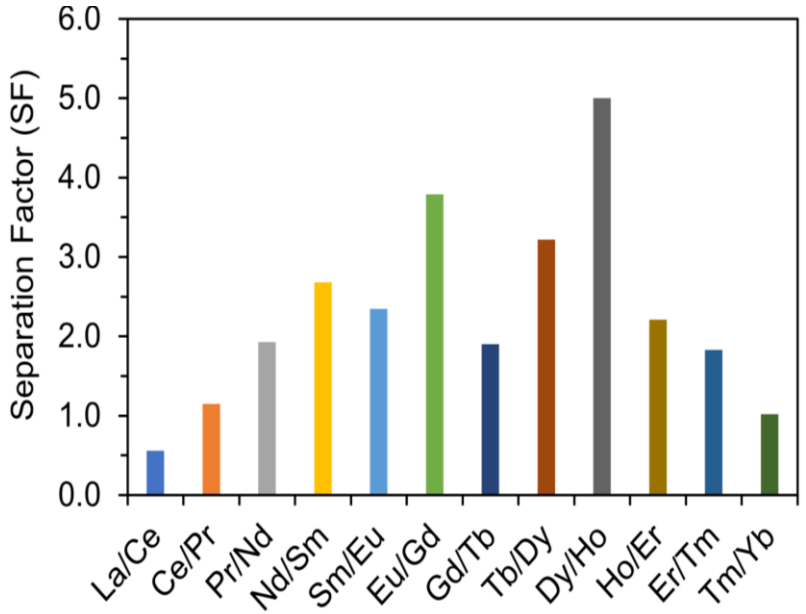
Flexible



Octadecyl Acyclopa (ODA)

$R = C_{18}H_{37}$

Flexible ligand



Flexible extractant delivers stiff size-based selectivity for critical Rare Earths

Next steps

Organization that leads developing a CMI/METALLIC technology leads in protecting and licensing it:

Lithium technologies developed by Oak Ridge National Laboratory and Licensed to Element3 for recovering lithium from produced water

Commercialization contact:

Leslie Smith, Commercialization Manager, smithlm@ornl.gov

CMI Headquarters contacts

Tom Lograsso, Director, CMIdirector@ameslab.gov

Stacy Joiner, Partner Relations, CMIaffiliates@ameslab.gov

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