

Critical Minerals

Systems Analysis Tasks



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*U.S. Department of Energy
National Energy Technology Laboratory
Resource Sustainability Project Review Meeting*

April 2, 2024

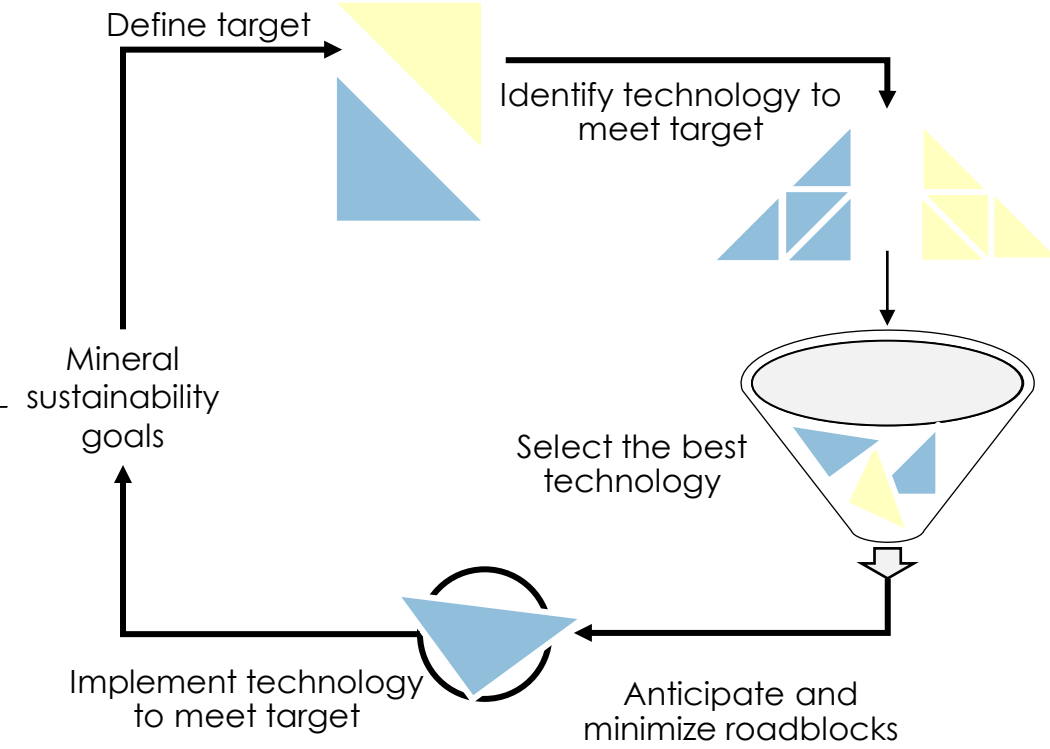
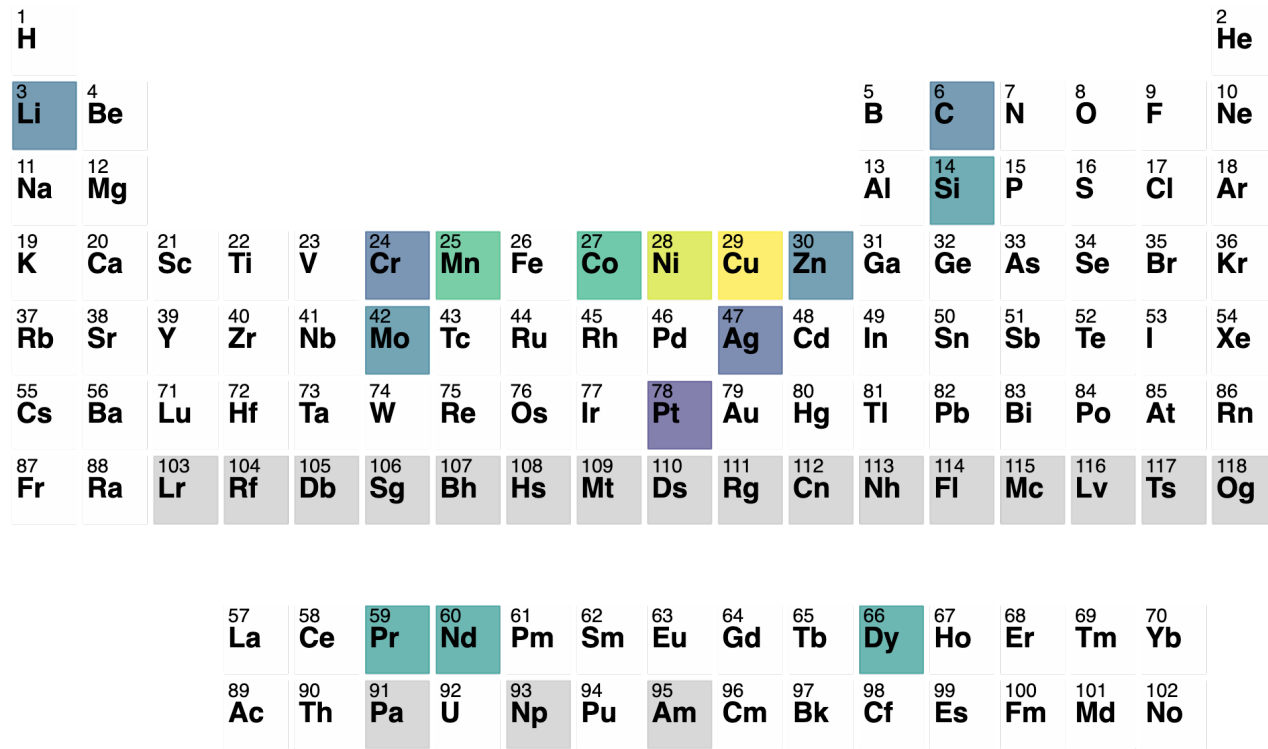
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HQ Program Manager: Mary Anne Alvin
Technology Manager: Jessica Mullen & Scott Montross*

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Critical Minerals: role of systems analysis



Critical Minerals EY23 Field Work Proposal



System Analysis Scope

Critical Minerals
Resource Data (Task
9)

Gabe Creason



Life Cycle Analysis
(Task 22)

Michelle Krynock



Shirley Sam



Tyler Davis



Markets Analysis
(Task 23)

Gavin Pickenpaugh



Jack Suter



Techno-Economic
Assessment (Task 25)

Alison Fritz



Chad Able



Tommy Schmitt

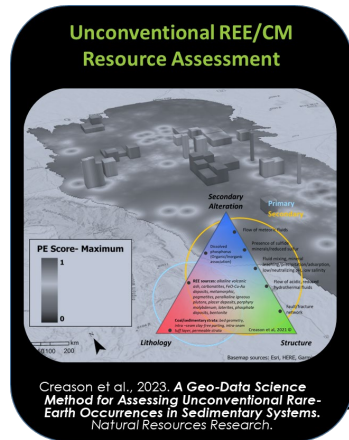


Critical Minerals EY23 Field Work Proposal

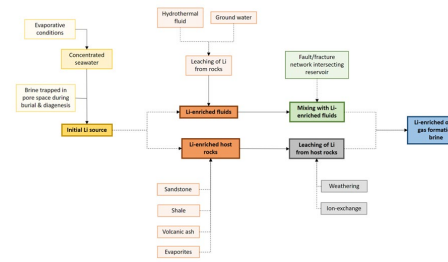
System Analysis Scope

Critical Minerals
Resource Data (Task
9)

Gabe Creason



Adapting the
Unconventional REE/CM
Resource Assessment
Method for Local-Scale
Application



Geospatial AI/ML-Driven
Pattern Discovery to
Identify Prospective
Unconventional CM
Resources

Adapting the Unconventional REE/CM Resource Assessment Method for Local-Scale Application

Objective

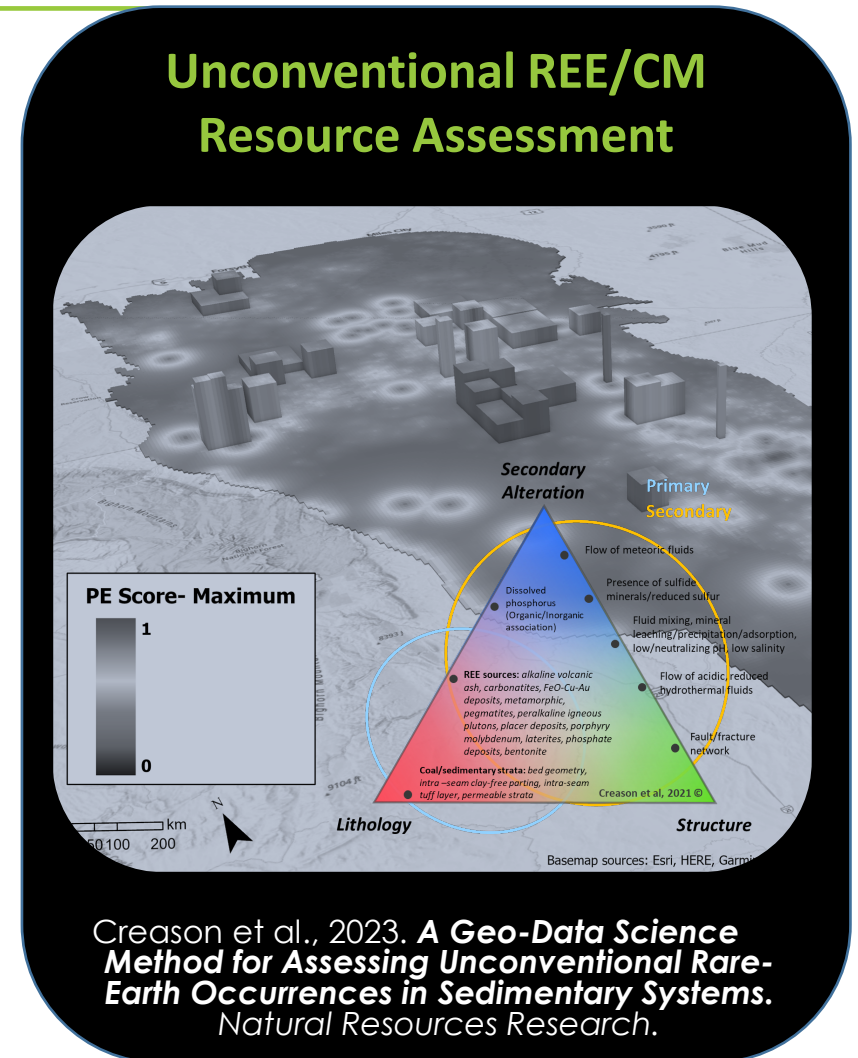
- Add capability to the NETL-RIC URC resource assessment method (Creason et al., 2023) to support local scale evaluation and quantification of in-place CM resource potential at sites for which higher resolution data are available.

Approach

- Establish new analytical approaches for three-dimensional analysis and characterization
- Incorporate additional data types into assessment
- Demonstration with case study

Outcome

- Accelerate TRL maturation of several NETL AI and software R&D REE/CM systems by demonstrating a commercial-scale test case and supporting the Minerals Sustainability Program interest in establishing a commercially viable domestic supply of REE and CMs.



Geospatial AI/ML-Driven Pattern Discovery to Identify Prospective Unconventional CM Resources

Objective

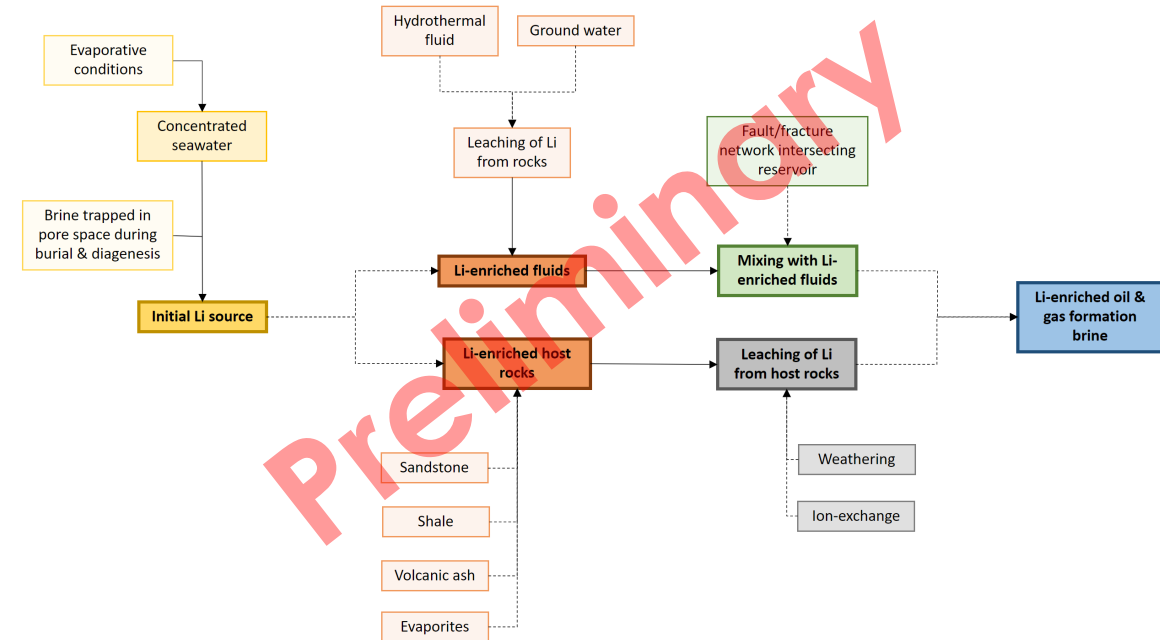
- Establish a new approach to identify and evaluate unconventional sources of additional critical minerals (e.g., lithium and other priority minerals)

Approach

- Develop a geospatial AI/ML-driven geochemical pattern discovery approach using geochemical and geophysical data
- Aggregate the current state of knowledge of systematic nature of CM accumulation (lithium) in geologic deposits
- Integrate that knowledge into the geologic processes-based framework of URC assessment method

Outcome

- Outputs from CM-specific geologic processes and geochemical modeling approaches will be integrated to provide new analytical tools for assessing unconventional CM resource potential in domestic sedimentary basins



Conceptualization of the geologic system relating to lithium enrichment in oil field brines.

Critical Minerals EY23 Field Work Proposal

System Analysis Scope

Life Cycle Analysis
(Task 22)

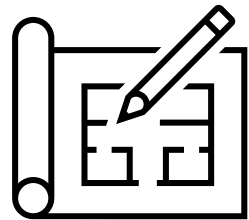
Michelle Krynock



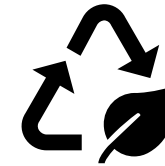
Shirley Sam



Tyler Davis



Critical Minerals LCA
Toolkit



Fly Ash Environmental
Assessment of
Alternative Actions



ISO Technical Advisory Group (TAG)
298 Working Group 5: Environmentally
Sustainable CM Mining, Separation,
and Processing Guidance

Critical Minerals EY23 Field Work Proposal

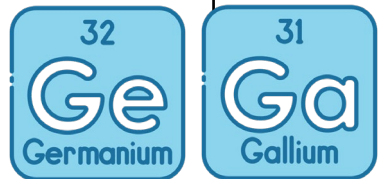
System Analysis Scope

Markets Analysis
(Task 23)

Gavin Pickenpaugh

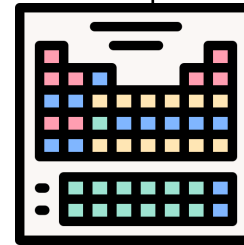


Jack Suter



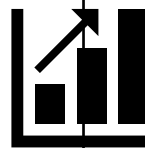
Source: Bearicons

Evaluation of market data for Gallium (Ga) and Germanium (Ge)



Source: Freepik

Updates to REE embedded demand database



Production and cost targets for REE

it

Embedded Demand of Ga and Ge

Objective

- Ga and Ge are critical to the energy transition.
- Supply of Ga and Ge is not secure due to export controls by competing nations.
- It is critical to understand U.S. reliance on imports containing these materials that are not currently measured.

Approach

- Determine what products imported into the U.S. include Ga and Ge.
- Estimate the Ga and Ge contained in these products.
- Calculate the total imports of these products.

Outcome

- Establish the embedded demand of Ga and Ge in imports to the U.S.



Source: The Aluminum Association



Source: WellPCB

Embedded Gallium: Bauxite to completed packaging and integration with circuit board

Identifying total demand of gallium embedded within all products consumed in the US in 2022

What products use gallium?

Semiconductors

Optoelectronics

Laser diodes

LEDs

Solar Cells (CIGS)

Copper Indium Gallium Selenide

Integrated Circuits (IC)
Power Electronics

Power Tools

Data Centers

Robots

Computers

Video Game Consoles

Medical Equipment

Telecom

Smartphones

Smart Grids

Motor Control

Inverters
(Wind, Solar, EVs, etc.)

Transportation
(auto/aviation)

Magnets

EV Motors

Wind Generators

Other Electric Machines

- Which of these products uses gallium instead of alternatives?

- Which of these products uses gallium instead of alternatives?
- What size chip do these products use?
- How many chips do they use?
- How much semiconductor material is used in those products?

- ★ Largest sources of demand
- ◆ Substitutable / Alternatives

Critical Minerals EY23 Field Work Proposal



System Analysis Scope

Techno-Economic Assessment (Task 25)

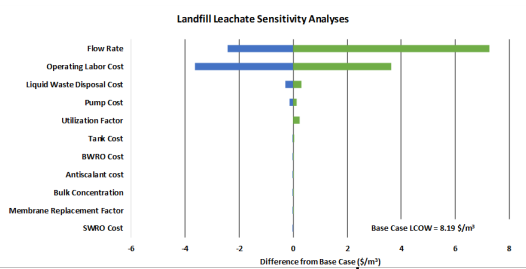
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Treatment and Critical Mineral Recovery Baseline for Leachate and Produced Waters



CO-DART
CONSTITUENT DATA REPLACEMENT TOOL

Machine Learning Approaches for Energy Wastewater Characterization

Machine Learning Approaches for Energy Wastewater Characterization

Objective

- Articulating more complete distributions of CMs in produced water and leachate allows for greater resolution in techno-economic analyses

Approach

- Gathered CM composition data from the Electric Power Research Institute Combustion Product Information (CPInfo) database, and NEWTS US Geological Survey (USGS) produced water data set.
- Performed modeling work in Python, leveraging the scikit-learn machine learning algorithms to build independent models for each constituent

Outcome

- Created a Python tool: Constituent Data Replacement Tool (CoDaRT) with a graphical user interface to replace missing data in energy wastewater datasets
- Produced REE estimates in leachate using coal ash data



The screenshot displays the graphical user interface for the Constituent Data Replacement Tool (CoDaRT). The interface is organized into several sections:

- File Help**: A menu bar at the top.
- Simulation Setup**: A tabbed interface with other tabs like Basic Inputs, Data Field Selection, Force Field Selection, Unit Field Selection, and Outputs/Execution.
- Algorithm Time**: A text input field.
- Correlation start point**: A text input field.
- Number of features**: A text input field.
- Minimum data threshold**: A text input field.
- Test Size**: A text input field.
- Random state value**: A text input field.
- Minimum Classification Threshold**: A text input field.
- Class Num**: A text input field.
- Error Calc Method**: A dropdown menu set to 'r2'.
- Error Threshold**: A text input field.
- Data Type**: A dropdown menu set to 'User'.
- Stratify**: A checked checkbox.
- Non Negatives**: A checked checkbox.
- Extrapolation**: A checked checkbox.
- Select Which Models you wish to use**: A section with a blue background containing several checkboxes:
 - Ridge
 - Lasso
 - Bagging Regression
 - AdaBoost
 - Multilayer Perceptron

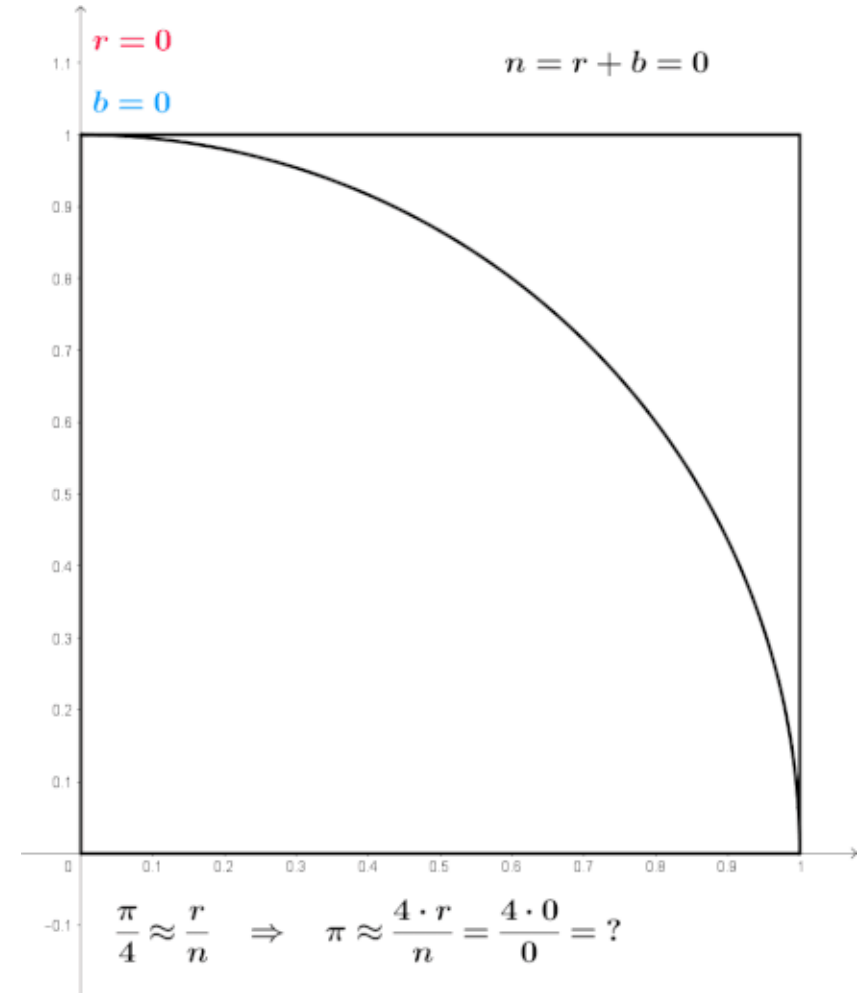


CO-DART
CONSTITUENT DATA REPLACEMENT TOOL

Graphical User Interface for CoDaRT

REEs in coal ash leachate estimated using CoDART data framework

- REE data is limited for leachate, but can be simulated using available data and methods
- Monte Carlo simulations were run to estimate the probability of REEs to be transferred from coal fly ash to leachate using REE data in coal fly ash, leaching ratios.



Used with permission from Kmhkmh*

Treatment and Byproduct Recovery Baseline for Leachate and Produced Waters

Objective

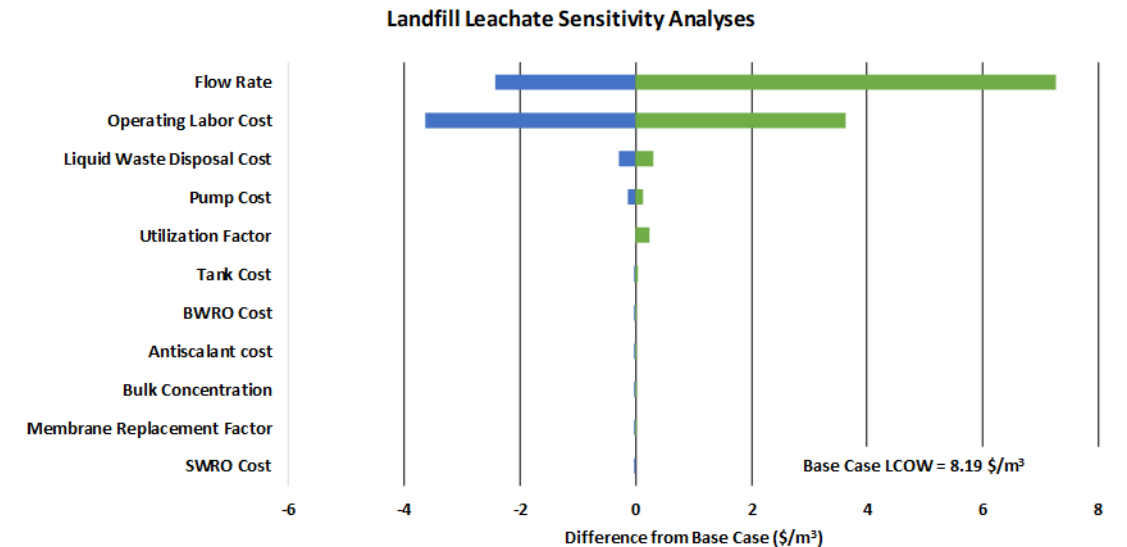
- The baseline cost of concentrating critical minerals during treatment of energy wastewaters can inform technology development and help build a domestic critical mineral supply.

Approach

- Modeled performance and cost of appropriate treatment and recovery systems for leachate and produced water in WaterTAP and OLI Studio and Flowsheet.
- Used CM market data available from the USGS for market value calculations.

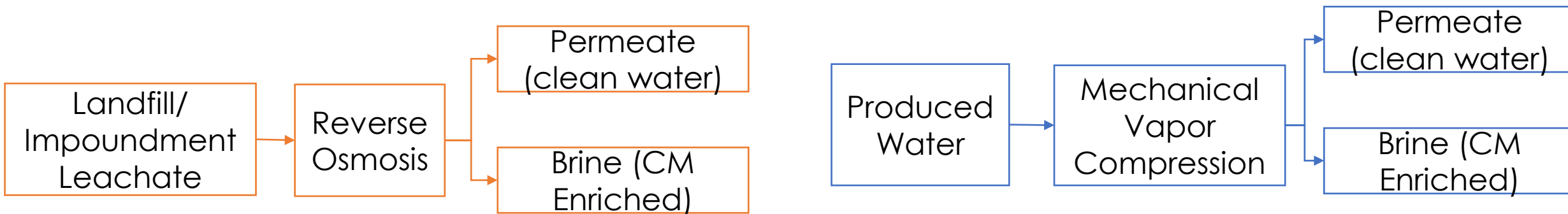
Outcome

- Produced performance and cost estimates for a membrane system for landfill and impoundment leachate and a mechanical vapor compression (MVC) system for produced water
- Calculated expected market value of critical minerals in the resultant brine.



Leachate treatment and mineral concentration costs are most dependent on flow rate and labor.

Treatment and Byproduct Recovery Baseline for Leachate and Produced Waters



Feedstock	Value of Brine (\$/m ³ permeate)	Levelized Cost of Water (\$2023/m ³)
Landfill Leachate	0.28	0.15-0.41
Impoundment Leachate	0.13	0.14– 0.39
Produced Water	15.44	3.00-6.51

Majority of value all brines is from lithium + magnesium

Upcoming Public Products



TOOLS/SOFTWARE
RELEASES

- NETL Critical Minerals LCA Guidance Toolkit
- "Machine Learning Approaches for Energy Wastewater Characterization" dataset completion tool.

Upcoming Public Products



TOOLS/SOFTWARE RELEASES

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- "Machine Learning Approaches for Energy Wastewater Characterization" dataset completion tool.



JOURNAL ARTICLES

- "Assessing Unconventional Rare-Earth Element Resource Potential in a Geologically Complex Sedimentary System: A Case Study from the Central Appalachian Basin (USA)". Justman, Creason, et al., in revision. Invited contribution to Special Issue in Applied Geochemistry.
- "Treatment and Byproduct Recovery Baseline for Leachate and Produced Waters". Able, Schmitt, Fritz et al.

Future directions

Current Expertise

Geospatial AI/ML

Process Systems
Engineering

Techno-economic
Assessment

Market Assessment

Life Cycle Analysis

New Domains

National Prospectus

Supply Chain Network
Model

Justice40 Toolset

Existing Domains

Inform R&D targets and
project selection

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Thank you

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