United States Energy Association: A Catalog and Survey of Critical Materials Research Collaboration Between Industry and National Laboratories

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A Catalog of Critical Materials Research within the US National Laboratories

PROMOTING DOMESTIC AND INTERNATIONAL CONSENSUS ON FOSSIL ENERGY TECHNOLOGIES: CARBON CAPTURE AND STORAGE AND CLEAN ENERGY SYSTEMS

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Report Objective

In FY2021, the United States Energy Association (USEA) carried out a series of workshops on Critical Minerals Sustainability with Industry representatives and representatives of the majority of the Department of Energy's (DOE's) national laboratories. One of the problems identified by multiple workshop participants was a lack of awareness of the varying methods of collaboration between industry and the national laboratories. In response, the USEA contracted Battelle to connect with national laboratory researchers and centers working on Critical Materials Sustainability and identify mechanisms for collaboration between national laboratories and private industry. The final report contains the currently engaged national laboratory operations dedicated to critical materials (CM) research with contact information, a breakdown of CM funding from the federal government, and survey response summaries from industry and national laboratories stakeholders on the current efficacy of industry/national laboratories collaboration in CM Research.

This report catalogs the ongoing CM Research at U.S. national laboratories which will aid in identifying mechanisms by which industry and national laboratories can collaborate. Section 1 contains a summary of the types of CM Research being done by the national laboratories, specifically the Critical Materials Institute, a DOE Energy Innovation Hub that pulls together researchers primarily from national laboratories with academic and industry partners. A contact and research area table has also been compiled. Section 2 of this report contains a description of the federal funding towards CM research, and Section 3 summarizes the survey responses conducted with industry and national laboratories stakeholders on the current efficacy of CM research collaboration.

Report Narrative

Section 1: Critical Materials Research in the National Laboratories

The Critical Materials Institute

The Critical Materials Institute (CMI) is a DOE Energy Innovation Hub housed at Ames National Laboratory launched in 2013[1]. CMI is comprised of national laboratories, universities, and businesses that seek innovations in CM research for domestic supply chain security.

The CMI creates intellectual property, develops facilities, and licenses technology to industry. The CMI has facilitated many research projects that have generated intellectual property. In its eight- year history (as of 2021), the CMI boasted 156 Intellectual Property Disclosure and Records (IPDR), and 25 patents. The complete list is available at www.ameslab.gov/cmi/cmi-invention-disclosures. The CMI currently supports 43 projects (Table 1), 9 of which were competitively selected in October 2021 as Open Innovation Projects.

[1] https://www.ameslab.gov/cmi/about-critical-materials-institute

Table 1. Areas and current research projects (FY21) in the CMI[2]

Diversifying Supply Expanding sources, transformative processes, new uses for co-products	•Lithium Extraction and Conversion from Brines •Critical Material Recovery from Ores and Lean Sources •Recovery of Critical Materials as By-Products •Biologically-Mediated Recovery of Tellurium from Mine Waste •Physico-chemical Beneficiation of Cobalt-bearing Iron Creek Ores (OIP) •Dissolution by Design: Selective Leaching of Rare Earth Elements Using Smart Lixiviants •Gallium, Indium, and Germanium Extraction from Zinc Residue Produced for Steel Wastes •New In-Silico Molecular Design Methods for Improved Separations •Enhanced Separation of Critical Materials •Unlocking Domestic Cobalt Production through Electrochemical Capture of Arsenic •Science-Enabling Diverse Value Chain Product from Aluminum-Cerium Alloys
Driving Reuse and Recycling Learning to use available materials more efficiently by reducing waste in manufacturing and increasing recycling	•Lithium, Cobalt, and Platinum Group Metals Recovery from Lithium-ion Batteries and Electronic Waste •Sustainable Biorecovery of Critical Elements from Lithium Ion Batteries •Sulfur Dioxide Leaching and Electrowinning for the Recovery of Cobalt, Lithium, and Manganese from Lithium Ion Battery (LIB) Cake *OIP) •Separation and Recovery of Cobalt from Energy Storage Devices •Cerium Gettering of Copper and Iron in Aluminum Alloy Recycling •Biomaterials for Critical Material Dissolution, Recovery, and Separation •Switchable Solvent Dewatering from Recovery of Critical Materials •Low Temperature Electrochemical Processing of Rare Elements •Recovery of Critical Materials from Dilute Electronic Waste Streams• Low-Temperature Chemical-Mediated Reduction of Rare Earth Elements •Low-Temperature Rare Earth Element (REE) Metal Production
Developing Substitutes Synthesizing materials that meet needs but use less critical resources e.g. magnets with reduced rare earth content	•Additive Manufacturing of Polymer-Based Bonded Magnets •Magnetic Materials and Systems Modeling •Reduced Rare Earth Content High Performance Magnets •Heterogeneous Samarium-Cobalt and Neodymium-Iron-Boron Magnets •Predicting Magnetic Anisotropy • •Application Targeted Magnetic Materials •Samarium-Iron-Nitrogen as a Cost-Effective High-Performance Magnet •Enhancing HDDR Powders •Novel Permanent Magnet Based on Highly Anisotropic Terbium-Copper-type Compounds •Preparation, Evaluation, and Characterization of Rare Earth Alloys Directly from Oxide Intermediates
Cross-cutting Research Developing new research tools and forecast what materials might become critical in the future. Sustainability and supply chain analysis are components.	•Advanced Search for High-Performance Materials (AS4HPM) •Machine Learning Materials Design •Accelerated Alloy Development and Rapid Assessment •Crosscutting Thermodynamic Properties of Critical Materials •Biogeochemical Impacts of Wastes from Critical Materials Recovery •Roadmaps for Technology Development •Impact of Research on Global Material Supply Chains •Optimizing the Economic Performance of CMI Technologies •Criticality, Life Cycles, Material Flows, and Scenarios

The CMI has a vast number of members from national laboratories, universities, and industry. Ames, Idaho, Lawrence Livermore, and Oak Ridge are national laboratory CMI members, and the National Energy Technology Laboratory is a CMI affiliate member. Importantly, the CMI allows team and affiliate members from industry. Table 2 below lists the industry team and affiliate members.

[2] https://iastate.app.box.com/v/cmi-annual-report

Table 2. Industry team and affiliate members of the CMI

Team Member	Affiliate Member
Advanced Magnet Lab, Inc. (AML)	American Battery Metals Corporation
All American Lithium	Aqua Metals, Inc.
American Manganese	Chateau Paris Estates
Arnold Magnetic Technologies	CleanLites Recycling
Big Blue Technologies (BBT)	Critical Materials Corporation
BorgWarner	Current Lighting Solutions
Eck Industries, Inc.	Elemental Earth Tech (formerly CHC Rare Earths)
Electra Battery Materials Corp. (formerly First Cobalt)	Emerson Electric
Electron Energy Corporation (EEC)	Energy Exploration Technologies (EnergyX)
Emrgy	Energy Fuels Resources USA
First Solar	Indium Corporation
Lixivia	MC Technologies
Irish Metals	MP Materials
Marshallton Research Laboratories	Ocean Minerals
Mercury Marine	P2PTechnologies
Momentum Technologies	Pajarito Powder
OLI Systems, Inc.	Phinix
Powdermet	Phoenix Tailings
REQYRD	Piedmont Lithium Carolinas, Inc.
Retriev Technologies	Pinzon Metals
Rio Tinto	ProChem, Inc.
Seegence Holdings, Inc.	Sil-Chlor
Shiloh Industries (purchased by Aludyne)	Southern Company Services
Spiers New Technologies	South Star Battery Metals Corp
TdVib	Ucore Rare Metals
Telex	Urbix
Terves	Western Digital Resources
U.S. Borax	Wyonics
Western Rare Earths	

Corporations, non-profits, and universities can be members of the CMI. Team members perform subcontracted research and/or provide cost share funds, which enable them to co-own IP, drive R&D, and license CMI technologies for deployment. Affiliate members pay a fee to receive CMI news, developments, and first public notice of IP available for licensing, but do not have authority to shape or provide input to the CMI research areas. A type of membership also exists that involves leveraging DOE-approved contractual mechanisms to conduct research and development, such as a Cooperate Research and Development Agreement (CRADA) or Strategic Partnership Project (SPP).

Stacy Joiner is the partnership specialist, and a previous DOE technology transfer manager, who manages partner relations and promote commercialization of CMI technology. CMI's vision is two-fold: (1) to have IP licensed and adopted by industry through partnerships and (2) for domestic small businesses to engage in federal research and development with potential for commercialization. The CMI and its partners have received funding awards from the DOE's Office of Technology Transitions Technology Commercialization Fund (TCF) and the Small

Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) program, as shown in Table 3.

Table 3. Federally-funded National Laboratories – Industry collaboration projects via TCF/SBIR/STTR (From FY20 report)

Entities	Mechanism	Project
Ames National Laboratory + Electron Energy Corporation	TCF	Mechanically robust high magnetic performance Sm-Co sintered magnets
Oak Ridge National Laboratory + Idaho National Laboratory + All American Lithium	TCF	Recovery of lithium from geothermal brine with lithium-aluminum-layered double hydroxide chloride sorbents
Lawrence Livermore National Laboratory + MolyWorks	TCF	Materials Design Simulator: A practical tool for advanced alloys development
TdVib (with Ames' technology)	STTR	Scale up acid-free dissolution recycling of critical materials from e-waste
Quantum Ventura Inc. (with INL's technology)	STTR	Scale up electrochemical recycling electronic constituents of value (E-RECOV)

While there exist many university-national lab collaborations that will not be specifically addressed here, one particular partnership between the National Energy Technology Laboratory and the University of Wyoming resulted in a Technology Commercialization Fund (TCF) from the DOE in 2020[3]. This work will culminate in pilot scale extraction of REEs from Powder River Basin coal feedstocks.

National Lab Critical Materials Research

The main scientists, engineers, and project managers doing Critical Materials Research at the national laboratories are listed with their contact information and research interests in Table 4. Researchers from non-CMI national laboratories are included as well. A list of patents from the past five years coming from national laboratories is included as an Excel spreadsheet; Attachment A.

Table 4. National laboratories, researchers performing Critical Materials work, their contact information, and areas of research interest

Principal Investigator	Contact Information	Research Interests
Ames National Laboratory		
Ikenna Nlebedim	Not available or not permitted to share at time of publication	Acid free dissolution of magnets for reuse (recycling) and production of magnets
Theresa Windus	twindus@iastate.edu	Computational chemistry, reaction optimization and automation
Marilu Perez Garcia	marilu@ameslab.gov	Metal ion-ligand binding as it relates to solvent extraction using computational chemistry
Denis Prodius	Not available or not permitted to share at time of publication	Recycling recovering and separation of rare earth metals from wide range of feedstocks including electronic wastes
Long Qi	Not available or not permitted to share at time of publication	Rare earth recovery with ligands

[3] NETL Collaboration Awarded Funding to Advance REE Extraction Technology https://netl.doe.gov/node/9840

Principal Investigator	Contact Information	Research Interests
Boazhi Cui	bcui@ameslab.gov	Reduction of critical materials in rare earth magnets
Jun Cui	Not available or not permitted to share at time of publication	Application-targeted magnetic materials
Ihor Hlova	Not available or not permitted to share at time of publication	Scalable synthesis of rare earth free/lean magnetic powders
Tom Lograsso (CMI Director)	cmidirector@ameslab.gov	Novel materials preparation and processing for rare earth substitutes
Andriy Palasyuk	Not available or not permitted to share at time of publication	Phase equilibria, crystal structure, and physical properties of rare earth intermetallic systems. New magnetic materials and alternatives for REE in permanent magnets
Durga Paudyal	Not available or not permitted to share at time of publication	Magnetic anisotropy
Tanya Prozorov	Not available or not permitted to share at time of publication	Geo-inspired separation of rare earth elements
Vitalij Percharsky	vitkp@ameslab.gov	Mechanochemical extraction of lithium at low temperatures from domestic a-spodumenes. SmFeN magnets. Deployable rare earth mineralization methods
Ryan Ott	Not available or not permitted to share at time of publication	Rapid assessment methodologies including 3D printing for discovering new materials. Al recycling improvements via additions of overly produced lanthanides (e.g., finding high volume applications for Ce)
Argonne National Laboratory		
Allison Bennet Irion (Group Leader)	Not available or not permitted to share at time of publication	Rare earth supply chain security supporting DOD's DLA
Diane Graziano	graziano@anl.gov	Critical material supply chain decision science
Braeton James Smith	smithb@anl.gov	Critical material supply chains
Nwike Iloeje	ciloeje@anl.gov	Thermodynamic modeling and technoeconomic optimization of critical materials recovery, multiphase separations for critical materials recovery
Matthew E. Riddle	Not available or not permitted to share at time of publication	Lead developer of GCMat (agent-based market model of global critical material supply chains)
Jessica Durham Macholz	jdurham@anl.gov	ReCell Center for Advanced Battery Recycling
Tim Fister	Not available or not permitted to share at time of publication	Continuous high yield production of defect-free, ultrathin sulfide glass electrolytes for next generation solid-state lithium metal batteries
Trevor Dzwiniel	Not available or not permitted to share at time of publication	Scale up production of graphene for next generation lithium-ion batteries

Principal Investigator	Contact Information	Research Interests
Michael Servis	mservis@anl.gov	Probing phase transitions and mesoscale aggregation in liquid-liquid extraction of rare earth elements
Jeff Spangenberger	Not available or not permitted to share at time of publication	Director of ReCell Center for Advanced Battery Recycling
Bryant Polzin	Not available or not permitted to share at time of publication	Deputy Director of ReCell Center for Advanced Battery Recycling
Matthew Robert Earlam	Not available or not permitted to share at time of publication	Extractive metallurgy of rare earths, magnesium, lithium
John N. Hryn	Not available or not permitted to share at time of publication	Energy efficient manufacturing and nanomanufacturing
Brookhaven National Laboratory		
Peter Khalifah	kpete@bnl.gov	Lithium batteries
Zonhai Chen	Not available or not permitted to share at time of publication	Commercially viable process for surface conditioning of high-nickel low-cobalt cathodes
Idaho National Laboratory		
Yoshiko Fujita	Yoshiko.fujita@inl.gov	Biogeochemical impacts of wastes from critical materials recovery, biorecovery of tellurium from mining wastes
Luis Diaz Aldana	Not available or not permitted to share at time of publication	Electrochemical recovery of metals from electronic waste
Kevin Lyon	Not available or not permitted to share at time of publication	Enhanced separation of critical materials
Prabhat Tripathy	prabhat.tripathy@inl.gov	Materials electrochemistry for producing rare earth metals/alloys and recovering critical elements from waste (including electronic)
David Reed	David.reed@inl.gov	Biomaterials for critical material dissolution, recovery, and separation
Dan Ginosar	daniel.ginosar@inl.gov	Recycling rare earth metals, advanced manufacturing, and intelligent controls
Tedd Lister	Not available or not permitted to share at time of publication	Electrochemical dissolution of electronic waste critical materials
Aaron Wilson	Aaron.wilson@inl.gov	Chemical separations and fundamental solution theory
Ruby Nguyen	Not available or not permitted to share at time of publication	Human impacts on critical materials using systems modeling. Research impacts on supply chain given market dynamics
Emmanuel Ohene Opare	Not available or not permitted to share at time of publication	Roadmaps for technology development
Donna Baek	Not available or not permitted to share at time of publication	Supercritical carbon dioxide and ionic liquids for the extraction of actinides and lanthanides. Electrochemically reducing rare earth elements from room temperature ionic liquids
Robert Fox (Capture Manager)	Not available or not permitted to share at time of publication	Lanthanide and actinide separations
Mary E. Case	Not available or not permitted to share at time of publication	Solvent extraction for rare earths from end-of-life products
Eric Peterson	Not available or not permitted to share at time of publication	Recycling node of the REMADE Institute, strategic and critical materials

Principal Investigator	Contact Information	Research Interests
Lawrence Berkeley National Laboratory		
Patrick F. Dobson	pfdobson@lbl.gov	Extraction of rare earth elements and lithium from geothermal brines
Gao Liu	gliu@lbl.gov	Dissolvable crosslinked polymer binder for battery electrode recycling
Lawrence Livermore National Laboratory		
Eric Schwegler	Not available or not permitted to share at time of publication	Computational methods to understand and predict properties of materials and systems including electrodes, alloys, and fluids
Yongqin Jiao	jiao1@llnl.gov	Systems biology enabled biosystems design of microbes for rare earth binding ligands and rare earth recovery
Hunter Henderson	henderson67@llnlgov	Al-REE alloy development for advanced manufacturing
Scott McCall	Not available or not permitted to share at time of publication	Magnetism, materials criticality, energy security, and sustainability
Aurelien Perron	Not available or not permitted to share at time of publication	Reduction in critical element usage via computational thermodynamics and ab initio electronic structure calculations
Fei Zhou	zhou6@llnl.gov	Modeling advanced cerium aluminum alloys with machine learning. Atomistic modeling of rare earth magnets using advanced electronic structure tools and ML
Dan Park	Park36@llnl.gov	Bio-based extraction of rare earths
Ziye (Jesse) Dong	Not available or not permitted to share at time of publication	Cost-effective and environment-friendly biomaterials for recovery of rare earth elements (REEs)
Los Alamos National Laboratory		
Kirsten Sauer	Not available or not permitted to share at time of publication	Mining, extraction of lanthanides from ore
Filip Ronning	Not available or not permitted to share at time of publication	Uranium compounds
Osman El Atwani	Not available or not permitted to share at time of publication	New alloys and metallic materials
Samuel Clegg	Not available or not permitted to share at time of publication	Laser-based analysis of rare earth elements in coal materials
National Energy Technology Laboratory		
Christina Lopano	Christina.Lopano@netl.doe.gov	Mineralogy and Novel Extractions of Unconventional CM Resources
Burt Thomas	Burt.Thomas@netl.doe.gov	Critical Minerals in Produced Water
Mary Anne Alvin	Not available at time of publication	Rare Earth and Critical Minerals Technology manager
Kelly Rose	Kelly.Rose@netl.doe.gov	Resource Prediction Methodologies
McMahon Gray	Mac.Gray@netl.doe.gov	Separations
Dustin McIntyre	Dustin.Mcintyre@netl.doe.gov	Laser Induced Breakdown Spectroscopy
Circe Verba	Circe.verba@netl.doe.gov	Characterization
Thomas Tarka	Thomas.Tarka@netl.doe.gov	Systems Analysis
Djuna Gulliver	Djuna.Gulliver@netl.doe.gov	Geomicrobiology/Bioinformatics
Mengling Stuckman	Mengling.Stuckman@netl.doe.gov	Characterization and Extraction of Ash and AMD Source Material

Principal Investigator	Contact Information	Research Interests
Scott Montross	Scott.Montross@netl.doe.gov	Geological Characterization and Deposit Model Development
Morgan Summers	William.Summers@netl.doe.gov	CM Market Analyses
Fan Shi	Fan.Shi@netl.doe.gov	Functional Materials for CM Separations
John Baltrus	John.Baltrus@netl.doe.gov	Characterization and Sensor Development
National Renewable Energy Laboratory		
Maria Curry-Nkansah	Not available or not permitted to share at time of publication	Circular economy for energy materials
Anthony Burrell, Kyusung Park, Robert Tenent	Not available or not permitted to share at time of publication	Battery materials synthesis
Eric Karp	Not available or not permitted to share at time of publication	Separation science in chemical and mining processes
Matt Keyser	Not available or not permitted to share at time of publication	Battery reuse and recycling
Mark Nimlos	Not available or not permitted to share at time of publication	Renewable graphite for lithium-ion batteries
Oak Ridge National Laboratory		
Bruce Moyer	moyerba@ornl.gov	Separation science and technology, solvent extraction, ion exchange
David Parker	parkerds@ornl.gov	First principles techniques for magnets, thermoelectrics, ferroelectrics, and superconductors
Vyacheslav Bryantsev	bryantsevv@ornl.gov	Ion binding and recognition, adsorption at mineral surfaces, heavy elements separations, molten salt chemistry, materials for energy applications. Computational approaches and nonlinear vibrational spectroscopy.
Parans Paranthaman	paranthamanm@ornlgov	Additive manufacturing of permanent magnets. Previous work on lithium separation from geothermal brine and lithium- and sodium-ion battery development
Nikki Thiele	Not available or not permitted to share at time of publication	Iminoguanidinium-based scaffolds for selective anion recognition, molecular recognition from rare earth mineral dissolution, development of ligands to expand utility of diagnostic and therapeutic radiometals
Michael Kesler	keslerms@ornl.gov	Processing and characterization of permanent magnets
Ramesh R Bhave	bhaverr@ornl.gov	Membrane-based rare earth separation
Santa Jansone-Popova	Not available or not permitted to share at time of publication	Rare earth separations technology
Johnathan Harter	harterjj@ornl.gov	Robotic disassembly system for spent electric vehicle packs for recycling of critical materials
Pacific Northwest National Laboratory		
Michael Huesemann	michael.huesemann@pnnl.gov	Critical lanthanide extraction with sea algae from seawater (UNCLE-SAM)

Principal Investigator	Contact Information	Research Interests
Peter Sushko	Peter.sushko@pnnl.gov	Design of structural inhomogeneity to control functional properties, reducing demand for platinum group metals
Praveen Thallapally	Praveen.thallapally@pnnl.gov	Magnetic core shell approach to extract critical minerals from Geothermal brine and produced waters (REE, Li, Cs)
Sandia National Laboratory		
Guangping Xu	Not available or not permitted to share at time of publication	Rare earth metals from coal ash
Erik Spoerke	Not available or not permitted to share at time of publication	Bioinspired havesting of rare earth metals

The DOE also runs 28 Office of Science User Facilities, where the scientific community can perform research in key areas: Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BER), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), Nuclear Physics (NP), and Accelerator R&D and Production (ARDAP). Many of these user facilities are co-located with national laboratories[4]. Each user facility manages their access process, which involves peer review of a submitted proposal by individual or collaborative research groups via open call for proposals. Legal user agreements signed ahead of time cover intellectual property and data rights, enabling entities to work on proprietary research at the user facility of interest.

Section 2: Government Engagement

The sustainability of the CM supply chain is an issue that has strong bipartisan support and has garnered attention across multiple White House administrations. Over the past several years, the government began taking a holistic approach to addressing CM shortfalls, requiring support from multiple government agencies. The degree of participation has varied from agency to agency with varying levels of funding and different motivations for investing in critical minerals.

The DOE has historically focused on the fossil fuel industry by pursuing projects that mitigate environmental impacts of conventional resource extraction, that extract CM from coal or coal by-products and that diversify the job portfolio of the coal industry[5]. Their most mature projects include three first-of-a-kind REE and CM pilot scale facilities that have produced high purity, mixed rare earth oxide (MREO) concentrates of 80–99 wt.% purity from diverse coal-based materials, including coal refuse, acid mine drainage, and power generation ash[6].

There are various offices who contribute to CM research within DOE, including the office of Fossil Energy and Carbon Management (FECM), the office of Energy Efficiency and Renewable Energy (EERE), the office of Science, and the Advanced Research Projects Agency–Energy

[4] US DOE Office of Science User Facilities, FY22. https://science.osti.gov/-/media/_/pdf/user-facilities/official-list/Office_of_Science_User_Facilities_FY_2022.pdf
[5] U.S. Department of Energy. *Recovery of Rare Earth Elements and Critical Materials from Coal and Coal Byproducts* Report to Congress May 2022; Pg. 11
[6] National Energy Technology Laboratory. *CRITICAL MINERALS SUSTAINABILITY PROGRAM* https://www.netl.doe.gov/coal/rare-earth-elements/program-overview/background

(ARPA-E)[7]. DOE reports obligating $217 million across the department on critical minerals and materials in FY21, received $210M under a Continuing resolution for FY 22 and requested $401 million in the President's budget for FY23. While the CMI was funded through the Advanced Manufacturing Office (part of EERE), FECM funding has flowed to three main paths: (1) in-house NETL funded research targeting unconventional REE resources, (2) NETL managed extramural projects, and (3) lab call field work proposals.

The Bi-partisan Infrastructure Law (BIL) is providing nearly $600 million for CM activities across fiscal years 2022 and 2023, including $140 million to establish a Rare Earth Elements Demonstration Facility and $75 million to establish a Critical Material Supply Chain Research Facility[8]. Since the BIL includes historic investments into clean energy systems, there are now more pressing requirements for CM. DOE has broadened its approach to include R&D in REE and CM alternatives, as well as recycling.

The Department of Defense (DOD) views REE and CM as vital to our national defense and economic prosperity. They also improve our warfighting capability, support family-sustaining jobs, and strengthen our alliances and partnerships[9]. With this perspective, DOD has made significant investments in conventional sources of REE and CM over the past few years. Most of this funding has been obligated through the Defense Production Act (DPA), passed in 1950, which allows the president to direct economic activity to support US national defense. In June of 2022, Lynas announced a $120 million follow on contract with the US DOD to establish a commercial heavy rare earths (HRE) separation facility in the United States[10]. In February of 2022[11], DOD also invested $35 million through the Industrial Base Analysis and Sustainment Program to MP Materials Corp. (MP) of Las Vegas, Nevada, to design and build a facility to process heavy rare earth elements (HREE). In July, 2021, the Defense Advanced Research Projects Agency (DARPA) announced its new Environmental Microbes as a BioEngineering Resource (EMBER) program with an objective to strengthen the supply chain by utilizing bioengineering approaches to facilitate REE separation and purification[12]. DARPA partnered with the United States Geological Survey (USGS) in August 2022 to establish a Critical Minerals Competition using AI and analytics to automate aspects of the USGS's critical mineral assessments[13].

There are various other government agencies that also contribute to REE and CM in various ways. The Environmental Protection Agency (EPA) is interested in waste mitigation and has contributed R&D funds into electronic waste recycling. The Department of Interior received $320

[7] U.S. Department of Energy *Recovery of Rare Earth Elements and Critical Materials from Coal and Coal Byproducts* Report to Congress May 2022; Pg. 13

[8] , 117th Congress (2021-2022); *H.R.3684 - Infrastructure Investment and Jobs Act;* Pg. 532 & pg. 700

[9] Department of Defense *Securing Defense-Critical Supply Chains,* February 2022; Pg. 42

[10]Menon, Praveen & Sharma, Riya; *Reuters Australia's Lynas gets $120 mln Pentagon contract for U.S. rare earths project* June 2022 https://www.reuters.com/markets/us/australias-lynas-secures-120-mln-pentagon-contract-us-rare-earths-facility-2022-06-14/

[11] Sloustcher, Matt. businesswire *MP Materials Awarded Department of Defense Heavy Rare Earth Processing Contract.* February 22, 2022 https://www.businesswire.com/news/home/20220221005456/en/

[12]Defense Advanced Research Projects *Agency Developing Cohesive, Domestic Rare Earth Element (REE) Technologies*. July 13, 2021 https://www.darpa.mil/news-events/2021-07-13

[13] Defense Advanced Research Projects *DARPA Critical Minerals Competition uses AI to Accelerate Analytics.* August 15, 2022 https://www.darpa.mil/news-events/2022-08-15

million towards the USGS Earth Mapping Resource Initiative (Earth MRI), to accelerate the identification of areas with potential critical mineral resources still in the ground and in mine wastes[14]. The National Science Foundation, in their FY 2023 President's Budget request, has over $1.5 billion to address the challenges of climate change and to develop novel clean energy solutions. These research investments include a focus on critical minerals needed for clean energy technology.

Section 3: Survey of National laboratories and Industry

We asked the CMI and non-CMI national laboratories and relevant industry stakeholders their perspectives on the collaborative environment for critical materials research. We received responses from the CMI and three non-CMI national laboratories, and four industry stakeholders: two small businesses and two medium-large sized businesses. We surveyed through email and/or virtual meetings with the following questions:

1) What is your current impression of the collaboration process with (national laboratories/industry) in the CM space?
2) Have you collaborated with a (national laboratory/industry) before on CM research? What was that process like, and were there desirable outcomes for your organization?
3) Are you aware of funding mechanisms for collaborative efforts between industry and national laboratories in CM research? Is the process of securing funding straightforward?
4) Can you think of any ways the collaborative efforts between industry and national labs could be improved?
5) What do you believe are important next steps in commercialization of CM technologies?

Response from industry stakeholders

Main concepts mentioned in the survey

- Friendly relations and collaborations with national laboratories partners have been formed, but do not often seem to materialize into organized research projects
- Industry interests and national laboratories interests are not always aligned (e.g. fundamental research vs. scaled production facilities)
- National laboratories research focuses should be shaped by identification of buyers/users of downstream technologies and solving issues related to supply-chain issues
- Difficult to identify the right partners without prior knowledge or working relationships
- Current funding mechanisms are limited in their ability to incentivize or facilitate collaboration
- Small businesses may be more amenable than large businesses in collaborating with national laboratories, but funding mechanisms seem to be limited to SBIR/STTR calls
- Cost share is always a challenge, especially for smaller businesses
- Industry stakeholders are not always aware of current funding opportunities

[14] 117th Congress (2021-2022) *H.R.3684 - Infrastructure Investment and Jobs Act*; Pg. 530

- Existing national laboratories commercialization strategies are lacking that benefit industry
- Most industry members were unaware of, or didn't feel it was worth the effort to, work within the CMI commercialization strategy
- Industry members felt economically viable CM commercialization is years away and more collaboration and government incentives are needed

Response from National Laboratory stakeholders

- The issues industry stakeholders face, and potential solutions the national laboratories could research, are unclear to the national laboratories
- Industry, generally, does not appear interested in the national laboratories technologies despite the potential for helpful analytical techniques and R&D advances
- There are challenges getting members of industry to collaborate with one another
- National laboratories collaboration with industry in the battery field appears to be more mature than for other critical materials (examples: Li Bridge, MERF, EcoCar EV challenge)
- There are user facilities at some national laboratories where industry can do proprietary research with the national laboratories
- The CMI has partner and teaming opportunities at various levels as well as a technology commercialization process where industry can license the IP from the national laboratories
- The CMI does not issue RFPs but statements of work can be developed for organizations to work with the CMI, and this also allows flexibility for entities to work with the CMI on new issues

Recommendations

Recommendations from surveyed entities include but are not limited to:

- Project managers experienced with commercialization should help manage the finances of collaborative efforts between national laboratories and industry, rather than scientists and researchers
- A more targeted outreach program, with detailed information on projects and researchers at the national laboratories, would be helpful. Some ideas included a regular email or newsletter with projects seeking partners or areas of expertise sought
- When evaluating national laboratories researchers/laboratories internally or by funding agencies, successful and documented cooperation with industrial partners should be given the same weight as published scientific papers
- More Requests-for-information (RFI) from government agencies, open to national laboratories, academic, and industry researchers
- Proposal preparation should be short and fast with more programs funding 6-12 month projects with more focused goals
- Effective mechanisms for linking R&D and commercialization should be considered
- More open sharing of technology development through key performance indicators without revealing trade secrets, to avoid unnecessary duplication of efforts and to collaborate towards making CM supply chains stable domestically

- What lessons can be learned from collaborative efforts between national laboratories, academics, and industry in other research areas (e.g., pharmaceuticals, O&G, etc)?
- DOE could facilitate CRADA-protected consortia for open discussions on technology

ATTACHMENT A

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Publication Number	Publication Date	Title	Abstract	Application Date	Original Assignee(Applicant)	Current Assignee	Inventor Name
US20200002785A1	2020-01-02	Methods for recovery of rare earth elements from coal	Methods of recovering rare earth elements, vanadium, cobalt, or lithium from coal are described. The coal is dissolved in a first solvent to dissolve organic material in the coal and create a slurry containing coal ash enriched with rare earth elements, vanadium, cobalt, or lithium. The enriched coal ash is separated from the first solvent. Residual organic material is removed from the coal ash. The rare earth elements, vanadium, cobalt, or lithium can then be recovered from the coal ash. The coal ash is mixed with an acid stream that dissolves the rare earth elements, thereby creating (i) a leachate containing the rare earth elements and (ii) leached ash. The leachate is heated to obtain acid vapor and an acid-soluble rare earth concentrate. The acid-soluble rare earth concentrate can be fed to a hydrometallurgical process to separate and purify the rare earth elements.	2019-08-15	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	PETERSON, RICK | HEINRICHS, MICHAEL | GADKARI, VINAY V. | TAHA, RACHID | WINECKI, SLAWOMIR | ARGUMENDO, DARWIN
US20210292870A1	2021-09-23	Methods of recovering an elemental rare earth metal, methods of forming a rare earth metal, and related systems	A method of removing of recovering an elemental rare earth metal comprises placing a rare earth-containing material comprising a rare earth metal in a reaction solution comprising a reducing agent and a non-aqueous solvent comprising an ionic liquid or a eutectic mixture, reducing the rare earth metal with the reducing agent to form a metallic rare earth metal and cations of the reducing agent, transferring the cations of the reducing agent from the reaction solution to an electrochemical cell through an ion exchange membrane, and reducing the cations of the reducing agent in the electrochemical cell. Related methods of forming an elemental rare earth metal, and related systems are disclosed.	2021-02-25	BATTELLE ENERGY ALLIANCE, LLC	BATTELLE ENERGY ALLIANCE, LLC	CASE, MARY E. | FOX, ROBERT V. | BAEK, DONNA L.
US20220002840A1	2022-01-06	Methods for separation and recovery of rare earth elements from aqueous solutions using diglycolamide derivatives	A method for extracting rare earth elements from aqueous solution, comprising: (i) acidifying an aqueous solution containing said rare earth elements with an inorganic acid to result in an acidified aqueous solution containing said rare earth elements and containing the inorganic acid in a concentration of 1-12 M, wherein said rare earth elements are selected from lanthanides, actinides, or combination thereof, and (ii) contacting the acidified aqueous solution with an aqueous-insoluble hydrophobic solution comprising a rare earth extractant compound dissolved in an aqueous-insoluble hydrophobic solvent to result in extraction of one or more of the rare earth elements into the aqueous-insoluble hydrophobic solution by binding of the rare earth extractant compound to the one or more rare earth elements, wherein the rare earth extractant compound has the following structure: provided that at least one of the conditions (a)-(d) applies.	2021-07-02	UT-BATTELLE, LLC | BATTELLE ENERGY ALLIANCE, LLC	UT-BATTELLE, LLC | BATTELLE ENERGY ALLIANCE, LLC	JANSONE-POPOVA, SANTA | LYON, KEVIN L. | POPOVS, ILJA | MOYER, BRUCE A.
US20190226054A1	2019-07-25	Methods of recovering rare earth elements	A method of recovering a rare earth element. The method comprises dissolving a rare earth element magnetic material in a dissolution organic solvent and a β-diketone compound to form a dissolved rare earth element mixture. A rare earth element of the rare earth element magnetic material and the β-diketone compound are reacted to form a β-diketonate chelate complex and the dissolution organic solvent is removed. The β-diketonate chelate complex is removed using a separation organic solvent, and the β-diketonate chelate complex is recovered. Additional methods are also disclosed.	2019-01-22	BATTELLE ENERGY ALLIANCE, LLC	BATTELLE ENERGY ALLIANCE, LLC	KLAEHN, JOHN | ROLLINS, HARRY W. | MCNALLY, JOSHUA S.

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Publication Number	Publication Date	Title	Abstract	Application Date	Original Assignee(Applicant)	Current Assignee	Inventor Name
US10954585B2	2021-03-23	Methods of recovering rare earth elements	A method of recovering a rare earth element. The method comprises dissolving a rare earth element magnetic material in a dissolution organic solvent and a β-diketone compound to form a dissolved rare earth element mixture. A rare earth element of the rare earth element magnetic material and the β-diketone compound are reacted to form a β-diketonate chelate complex and the dissolution organic solvent is removed. The β-diketonate chelate complex is removed using a separation organic solvent, and the β-diketonate chelate complex is recovered. Additional methods are also disclosed.	2019-01-22	BATTELLE ENERGY ALLIANCE, LLC	BATTELLE ENERGY ALLIANCE, LLC	KLAEHN, JOHN | ROLLINS, HARRY W. | MCNALLY, JOSHUA S.
US20180312941A1	2018-11-01	Dissolution and separation of rare earth metals	A chemical dissolution method is provided for use in recycling rare earth metal-containing material such as permanent magnet material including end-of-life magnet shapes, magnet scrap and Terfenol-D alloy material by mixing the rare earth metal-containing material and an aqueous solution of a copper (II) salt to dissolve the material in the solution. The dissolved rare earth metal is then precipitated from the aqueous solution as a rare earth metal compound, such as a rare earth metal oxalate, sulfate or phosphate from which rare earth metal oxide can be obtained.	2018-06-25	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	MUDRING, ANJA-VERENA | PRODIUS, DENIS | NLEBEDIM, CAJETAN IKENNA
US10648063B2	2020-05-12	Dissolution and separation of rare earth metals	A chemical dissolution method is provided for use in recycling rare earth metal-containing material such as permanent magnet material including end-of-life magnet shapes, magnet scrap and Terfenol-D alloy material by mixing the rare earth metal-containing material and an aqueous solution of a copper (II) salt to dissolve the material in the solution. The dissolved rare earth metal is then precipitated from the aqueous solution as a rare earth metal compound, such as a rare earth metal oxalate, sulfate or phosphate from which rare earth metal oxide can be obtained.	2018-06-25	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	MUDRING, ANJA-VERENA | PRODIUS, DENIS | NLEBEDIM, CAJETAN IKENNA
US20170356067A1	2017-12-14	Acid digestion processes for recovery of rare earth elements from coal and coal byproducts	A system for recovering rare earth elements from coal ash includes a leaching reactor, an ash dryer downstream of the leaching reactor, and a roaster downstream of the ash dryer that is cooperatively connected to both the leaching reactor and the ash dryer. Coal ash is mixed with an acid stream such that rare earth elements present in the coal ash are dissolved in the acid stream, thereby creating (i) a leachate containing the rare earth elements and (ii) leached ash. The leachate is heated to obtain acid vapor and an acid-soluble rare earth concentrate. Mixing of the coal ash with the acid stream can occur in a leaching reactor and heating of the leachate can occur in a roaster. The acid-soluble rare earth concentrate can be fed to a hydrometallurgical process to separate and purify the rare earth elements.	2017-06-08	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	PETERSON, RICK | HEINRICHS, MICHAEL | GADKARI, VINAY V. | TAHA, RACHID | WINECKI, SLAWOMIR | ARGUMEDO, DARWIN
US10626482B2	2020-04-21	Acid digestion processes for recovery of rare earth elements from coal and coal byproducts	A system for recovering rare earth elements from coal ash includes a leaching reactor, an ash dryer downstream of the leaching reactor, and a roaster downstream of the ash dryer that is cooperatively connected to both the leaching reactor and the ash dryer. Coal ash is mixed with an acid stream such that rare earth elements present in the coal ash are dissolved in the acid stream, thereby creating (i) a leachate containing the rare earth elements and (ii) leached ash. The leachate is heated to obtain acid vapor and an acid-soluble rare earth concentrate. Mixing of the coal ash with the acid stream can occur in a leaching reactor and heating of the leachate can	2017-06-08	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	PETERSON, RICK | HEINRICHS, MICHAEL | GADKARI, VINAY V. | TAHA, RACHID | WINECKI, SLAWOMIR | ARGUMEDO, DARWIN

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			occur in a roaster. The acid-soluble rare earth concentrate can be fed to a hydrometallurgical process to separate and purify the rare earth elements.				
US20210198117A1	2021-07-01	Process for preparing doped lithium lanthanum zirconium oxide	A process for preparing doped-lithium lanthanum zirconium oxide (doped-LLZO) is described herein. The method involves dry doping of a co-precipitated lanthanum zirconium oxide (LZO) precursor. Dry doping is a process in which a dry powdered dopant is ground and mixed with a pre-prepared co-precipitated LZO precursor and a lithium salt to provide a LLZO precursor composition, which is subsequently calcined to form a doped-LLZO. The process described herein comprises calcining a dry, powdered (e.g., micron, sub-micron or nano-powdered) mixture of a co-precipitated LZO precursor, a dopant salt or oxide, and a lithium salt under an oxygen-containing atmosphere at a temperature in the range of about 500 to about 1100° C., and recovering the doped-LLZO after calcining.	2019-12-26	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	DURHAM, JESSICA L. | LIPSON, ALBERT L. | KAHVECIOGLU, OZGENUR
US20210376400A1	2021-12-02	Recovery of critical elements from end-of-life lithium ion batteries with supported membrane solvent extraction	Single-stage and multi-stage systems and methods for the recovery of critical elements in substantially pure form from lithium ion batteries are provided. The systems and methods include supported membrane solvent extraction using an immobilized organic phase within the pores of permeable hollow fibers. The permeable hollow fibers are contacted by a feed solution on one side, and a strip solution on another side, to provide the simultaneous extraction and stripping of elements from dissolved lithium ion cathode materials, while rejecting other elements from the feed solution. The single- and multi-stage systems and methods can selectively recover cobalt, manganese, nickel, lithium, aluminum and other elements from spent battery cathodes and are not limited by equilibrium constraints as compared to traditional solvent extraction processes.	2020-05-27	UT-BATTELLE, LLC	UT-BATTELLE, LLC	BHAVE, RAMESH R. | ISLAM, SYED Z. | WAGH, PRIYESH A.
US20200165735A1	2020-05-28	Actinide and rare earth drawdown system for molten salt recycle	A method for recycling molten salt from electrorefining processes, the method having the steps of collecting actinide metal using a first plurality of cathodes from an electrolyte bath, collecting rare earths metal using a second plurality of cathodes from the electrolyte bath, inserting the collected actinide metal and uranium into the bath, and chlorinating the inserted actinide metal and uranium. Also provided is a system for recycling molten salt, the system having a vessel adapted to receive and heat electrolyte salt, a first plurality of cathodes adapted to be removably inserted into the vessel, a second plurality of cathodes adapted to be removably inserted into the vessel, an anode positioned within the vessel so as to be coaxially aligned with the vessel, and a vehicle for inserting uranium into the salt.	2019-12-23	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	WILLIT, JAMES L. | TYLKA, MAGDALENA M. | WILLIAMSON, MARK A. | WIEDMEYER, STANLEY G. | FIGUEROA, JAVIER

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Publication Number	Publication Date	Title	Abstract	Application Date	Original Assignee(Applicant)	Current Assignee	Inventor Name
US20200227194A1	2020-07-16	System and Method for the Recycling of Rare Earth Magnets	A system and a method for separating and recycling magnets made from rare earth elements from an article of manufacture used an alignment device to property position the rare earth magnet for processing. Once proper alignment is made, a separating device removes the magnet and a portion of the article. A heating device demagnetizes the magnets and vibration causes the magnets to separate from the portion of the article. Electromagnets remove the portion of the article and the rare earth magnets pass through for reclamation.	2020-03-26	UT-BATTELLE, LLC	UT-BATTELLE, LLC	MCINTYRE, TIMOTHY J.
US11250980B2	2022-02-15	System and method for the recycling of rare earth magnets	A system and a method for separating and recycling magnets made from rare earth elements from an article of manufacture used an alignment device to property position the rare earth magnet for processing. Once proper alignment is made, a separating device removes the magnet and a portion of the article. A heating device demagnetizes the magnets and vibration causes the magnets to separate from the portion of the article. Electromagnets remove the portion of the article and the rare earth magnets pass through for reclamation.	2020-03-26	UT-BATTELLE, LLC	UT-BATTELLE, LLC	MCINTYRE, TIMOTHY J.
US20180195147A1	2018-07-12	Engineered microbes for rare earth element adsorption	This disclosure provides engineered microbes modified such that the surface of the microbe contains one or more rare earth element (REE) binding ligands, as well as methods of use thereof.	2017-01-06	REED, DAVID W. | LAWRENCE LIVERMORE NATIONAL SECURITY, LLC	LAWRENCE LIVERMORE NATIONAL SECURITY, LLC | BATTELLE ENERGY ALLIANCE, LLC	JIAO, YONGQIN | PARK, DAN MCFARLAND | YUNG, MIMI CHO | REED, DAVID W.
US10196708B2	2019-02-05	Engineered microbes for rare earth element adsorption	This disclosure provides engineered microbes modified such that the surface of the microbe contains one or more rare earth element (REE) binding ligands, as well as methods of use thereof.	2017-01-06	REED, DAVID W. | LAWRENCE LIVERMORE NATIONAL SECURITY, LLC	LAWRENCE LIVERMORE NATIONAL SECURITY, LLC | BATTELLE ENERGY ALLIANCE, LLC	JIAO, YONGQIN | PARK, DAN MCFARLAND | YUNG, MIMI CHO | REED, DAVID W.
US20190119778A1	2019-04-25	Engineered microbes for rare earth element adsorption	This disclosure provides engineered microbes modified such that the surface of the microbe contains one or more rare earth element (REE) binding ligands, as well as methods of use thereof.	2018-12-21	REED, DAVID W. | LAWRENCE LIVERMORE NATIONAL SECURITY, LLC	LAWRENCE LIVERMORE NATIONAL SECURITY, LLC | BATTELLE ENERGY ALLIANCE, LLC	JIAO, YONGQIN | PARK, DAN MCFARLAND | YUNG, MIMI CHO | REED, DAVID W.
US11230750B2	2022-01-25	Engineered microbes for rare earth element adsorption	Presently described are engineered microbes modified such that the surface of the microbe contains one or more rare earth element (REE) binding ligands, as well as methods of use thereof.	2018-12-21	REED, DAVID W. | LAWRENCE LIVERMORE NATIONAL SECURITY, LLC	LAWRENCE LIVERMORE NATIONAL SECURITY, LLC | BATTELLE ENERGY ALLIANCE, LLC	JIAO, YONGQIN | PARK, DAN MCFARLAND | YUNG, MIMI CHO | REED, DAVID W.

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Publication Number	Publication Date	Title	Abstract	Application Date	Original Assignee(Applicant)	Current Assignee	Inventor Name
US20200056264A1	2020-02-20	Separation of rare earth elements using supported membrane solvent extraction	A system and method for the recovery and separation of rare earth elements (REEs) are provided. The system and method include the supported membrane solvent extraction of REEs and the separation of light and heavy REEs that have been recovered from scrap permanent magnets and other electronic waste. In supported membrane solvent extraction, an organic phase consisting of an extractant and an organic solvent is immobilized in the pores of hollow fibers. An aqueous feed solution and a strip solution flow along the shell side and lumen side of the hollow fibers, respectively. The extractant functions as a carrier to selectively transport certain rare earth metal ions from the feed side to the strip side. The rare earth metals are concurrently back extracted in the strip solution, allowing processing to proceed continuously without equilibrium limitations.	2019-08-12	UT-BATTELLE, LLC	UT-BATTELLE, LLC	BHAVE, RAMESH R. | ISLAM, SYED Z.
US20190316225A1	2019-10-17	Extraction of rare earth elements and carbon rich solids from coal feedstock using ionic liquids	Rare earth elements and carbon rich solids are extracted from coal feedstock by combining a coal feedstock with an ionic liquid, forming a mixture. The mixture is heated and a co-solvent is added. Carbon rich solids and rare earth elements are removed from the solution. The ionic liquid and co-solvent may be reused.	2018-04-17	ENERGY, UNITED STATES DEPARTMENT OF	ENERGY, UNITED STATES DEPARTMENT OF	LI, CHENLIN | HE, TING | WILLIAMS, C. LUKE
US20200195101A1	2020-06-18	Automated recovery of rare earth permanent magnets from electric machines	A method and a system for the automated recovery of rare earth permanent magnets from electric machines are provided. The method and the system include identifying electric machines in a mixed product stream for performing a unique robotic disassembly routine. Electric machines that are not identified are diverted to a robot training station, during which time the system and the method include implementing a suitable disassembly routine. A conveyor delivers the remaining electric machines to a rotary platform having multiple stations for the simultaneous disassembly of multiple electric machines. Permanent magnets are removed from the electric machines and are then sorted for recycling operations.	2019-12-18	UT-BATTELLE, LLC	UT-BATTELLE, LLC	MCINTYRE, TIMOTHY J. | HARTER, JONATHAN J.
US20210320293A1	2021-10-14	Method for recovering lithium battery active cathode material from cathode waste	A method for recovering and recycling a cathode active material comprises combining a cathode waste from a lithium battery cathode waste stream with lithium-containing compound (e.g., lithium hydroxide) to form a reaction mixture; wherein the cathode waste comprises carbon, a fluorinated polymeric binder, and a cathode material selected from the group consisting of a lithiated cathode material and a delithiated cathode material; heating the reaction mixture in a stream of oxygen-containing gas to a temperature and for a period of time sufficient to burn off the carbon and the binder, to lithiate any delithiated cathode material present in the cathode waste, and for lithium in the reaction mixture to capture fluoride formed from decomposition of the binder; cooling the reaction mixture to ambient room temperature; and recovering the lithiated cathode active material.	2020-04-13	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	LIPSON, ALBERT L. | DURHAM, JESSICA L.

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Publication Number	Publication Date	Title	Abstract	Application Date	Original Assignee(Applicant)	Current Assignee	Inventor Name
US20220002229A1	2022-01-06	Diglycolamide derivatives for separation and recovery of rare earth elements from aqueous solutions	Rare earth extractant compounds having the following structure: wherein R1, R2, R3, and R4 are independently selected from alkyl groups containing 1-30 carbon atoms and optionally containing an ether or thioether linkage connecting between carbon atoms, provided that the total carbon atoms in R1, R2, R3, and R4 is at least 12; R5 and R6 are independently selected from hydrogen atom and alkyl groups containing 1-3 carbon atoms; and provided that at least one of the conditions (i)-(iv) apply as follows: presence of a distal branched group in at least one of R1-R4 (condition i), asymmetry in R1-R4 (condition ii), presence of amine-containing ring (condition iii), or presence of lactam ring (condition iv). Also described are hydrophobic water-insoluble solutions containing at least one extractant compound of Formula (1), as well as method for extracting rare earth elements from aqueous solution by contacting the aqueous solution with the water-insoluble solution.	2021-07-02	UT-BATTELLE, LLC	UT-BATTELLE, LLC	JANSONE-POPOVA, SANTA | POPOVS, ILJA | MOYER, BRUCE A.
US10418138B1	2019-09-17	Method of separating and recovering uranium from aluminum-clad metallic nuclear fuel	According to one aspect of the invention, a method for separating and recovering uranium from a nuclear fuel element. The method includes immersing a nuclear fuel element containing nuclear fuel and cladding in a molten metal. The nuclear fuel includes uranium. The cladding is selectively dissolved from the nuclear fuel element when immersed in the molten metal. The nuclear fuel is separated from the cladding. The method then includes loading the nuclear fuel into a permeable basket that is electrically configured as an anode of an electrolytic cell. There are also a molten salt electrolyte and a cathode in the electrolytic cell. Then, the method includes applying an electric charge across the electrolytic cell. The molten salt electrolyte selectively transfers uranium from the anode to the cathode.	2018-10-22	UNITED STATES DEPARTMENT OF ENERGY	U.S. DEPARTMENT OF ENERGY	HERRMANN, STEVEN | NORBASH, KEVIN
US20200106127A1	2020-04-02	Lithium metal recovery and synthesis	A process and system for creating a lithium ion anolyte from lithium alloys. Metal and lithium alloys are processed to remove the metal with lithium from the alloy remaining. A lithium ion anolyte formed may be used in a process to form lithium metal. Alternatively, a process and system for recovering lithium from sources such as lithium alloys and lithium metal oxides and other feedstock such as recycled batteries into a thin lithium metal film via electrodeposition in an organic electrolyte contacting both anode (holder for lithium source) and cathode (substrate for lithium deposition) in a single-compartment electrolysis cell.	2018-09-28	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	IGNACIO DE LEON, PATRICIA ANNE | HRYN, JOHN N. | TANG, LI | BARRY, EDWARD F. | ARENAS, DANIEL YOAV
US20210257685A1	2021-08-19	Efficient recovery processes for the black mass from spent lithium-ion batteries	A method of recycling lithium-ion batteries is disclosed. The method includes isolating a composite electrode that comprises an electrode material adhered to a current collector with a polyvinylidene difluoride (PVDF) binder from a spent lithium-ion battery. The method also includes contacting the composite electrode in a polyol fluid capable of releasing the PVDF binder from the current collector without substantially altering either component. The composite electrode may be a cathode or an anode. The method also includes rapidly delaminating the electrode material from the current collector to give a free electrode material and a free current collector, and recovering each of the free electrode material	2021-02-16	UT-BATTELLE, LLC	UT-BATTELLE, LLC	BELHAROUAK, ILIAS | BAI, YAOCAI | LI, JIANLIN

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Publication Number	Publication Date	Title	Abstract	Application Date	Original Assignee(Applicant)	Current Assignee	Inventor Name
			and the free current collector from the mixture. The free electrode material may be reused to prepare another composite electrode, as well as a lithium-ion battery comprising the same, which are also disclosed.				
US20210367235A1	2021-11-25	Stabilized lithium metal oxide electrode material and method of preparation	A stabilized lithium metal oxide cathode material comprises microparticles of lithium metal oxide in which individual particles thereof a core of lithium metal oxide and a coating of a different lithium metal oxide surrounding the core. There is an interface layer between the cores and the coatings in which there are gradients of metal ions in the direction of coating to core. The materials are made by a three stage process involving coprecipitating precursor metal hydroxide core particles at a controlled pH; coprecipitating a different metal hydroxide coating on the particles without controlling the pH; and then calcining the resulting coated precursor particles with lithium hydroxide to form the stabilized lithium metal oxide material.	2020-05-19	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	LIPSON, ALBERT L. | DURHAM, JESSICA L.
US20190275473A1	2019-09-12	Lithium extraction composite for recovery of lithium from brines, and process of using said composition	A lithium extraction composite comprising: (i) a porous support and (ii) particles of a lithium-selective sorbent material coated on at least one surface of the support, wherein the support has a planar membrane, fiber (or rod), or tubular shape. A method for extracting and recovering a lithium salt from an aqueous solution by use of the above-described composition is also described, the method comprising (a) flowing the aqueous source solution through a first zone or over a first surface of the lithium extraction composite to result in selective lithium intercalation in the lithium-selective sorbent material in the first zone or first surface; and (b) simultaneously recovering lithium salt extracted in step (a) from said lithium-selective sorbent material by flowing an aqueous stripping solution through a second zone or over a second surface of the lithium extraction composite in which lithium ions from the first zone or first surface diffuse.	2019-03-08	UT-BATTELLE, LLC | ALL AMERICAN LITHIUM LLC	UT-BATTELLE, LLC | TERRALITHIUM LLC	BHAVE, RAMESH R. | HARRISON, STEPHEN | MOYER, BRUCE A. | PARANTHAMAN, M. PARANS
US20200318219A1	2020-10-08	Mechanochemical recovery of Co, Li and other constituents from spent lithium-ion batteries	Method embodiments useful for recycling spent lithium-ion battery (LIB) electrodes to extract critical and/or valuable elements from LIBs are provided and involve mechanochemical processing of spent LIB electrodes in the presence of certain chemical agents to recover products that can include, but are not limited to, metallic solids such as elemental metals or metal alloys, and/or inorganic compounds, metal salts, or organometallic derivatives. The desired products can be separated from by-products and contaminants and further processed into LIB electrode materials or/and other substances.	2020-01-28	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	DOLOTKO, OLEKSANDR | BALEMA, VIKTOR | HLOVA, IHOR | GUPTA, SHALABH | MUDRYK, YAROSLAV | PECHARSKY, VITALIJ K.

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US11253820B2	2022-02-22	Lithium extraction composite for recovery of lithium from brines, and process of using said composition	A lithium extraction composite comprising: (i) a porous support and (ii) particles of a lithium-selective sorbent material coated on at least one surface of the support, wherein the support has a planar membrane, fiber (or rod), or tubular shape. A method for extracting and recovering a lithium salt from an aqueous solution by use of the above-described composition is also described, the method comprising (a) flowing the aqueous source solution through a first zone or over a first surface of the lithium extraction composite to result in selective lithium intercalation in the lithium-selective sorbent material in the first zone or first surface; and (b) simultaneously recovering lithium salt extracted in step (a) from said lithium-selective sorbent material by flowing an aqueous stripping solution through a second zone or over a second surface of the lithium extraction composite in which lithium ions from the first zone or first surface diffuse.	2019-03-08	UT-BATTELLE, LLC | ALL AMERICAN LITHIUM LLC	UT-BATTELLE, LLC | TERRALITHIUM LLC	BHAVE, RAMESH R. | HARRISON, STEPHEN | MOYER, BRUCE A. | PARANTHAMAN, M. PARANS
US20200002784A1	2020-01-02	Systems for acid digestion processes	A system for recovering rare earth elements from coal ash includes a leaching reactor, an ash dryer downstream of the leaching reactor, and a roaster downstream of the ash dryer that is cooperatively connected to both the leaching reactor and the ash dryer. Coal ash is mixed with an acid stream such that rare earth elements present in the coal ash are dissolved in the acid stream, thereby creating (i) a leachate containing the rare earth elements and (ii) leached ash. The leachate is heated to obtain acid vapor and an acid-soluble rare earth concentrate. Mixing of the coal ash with the acid stream can occur in a leaching reactor and heating of the leachate can occur in a roaster. The acid-soluble rare earth concentrate can be fed to a hydrometallurgical process to separate and purify the rare earth elements.	2019-08-15	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	PETERSON, RICK | HEINRICHS, MICHAEL | GADKARI, VINAY V. | TAHA, RACHID | WINECKI, SLAWOMIR | ARGUMEDO, DARWIN
US20180222761A1	2018-08-09	Selective lithium recovery as lithium carbonate from natural brines	Embodiments relate to methods, systems And apparatus tor generating lithium from brine. The brine is heated in a first vessel to greater than 260° C. and CO2 gas is injected mixing with the brine such that the CO2/P is greater than 18 g/atm. The brine is held at greater than 18 g/atm for longer than 20 minutes so that any impurities precipitate as solids leaving only lithium ions and chlorine ions. The brine is moved to a second vessel screening out solid precipitates leaving a brine containing only chlorine and lithium. CO2 gas is injected and mixed with the brine at 260° C. so that the CO2/P is greater than 200 g/atm. The brine is held at greater than 200 g/atm for longer than 20 minutes suppressing the chlorine as dissolved ions while lithium precipitates out as lithium carbonate. The lithium carbonate precipitate is removed from the brine solution.	2017-10-10	ENERGY, UNITED STATES DEPARTMENT OF	U.S. DEPARTMENT OF ENERGY	Nakano Jinichiro | Nakano Anna | Bennett James P.
US10315926B2	2019-06-11	Selective lithium recovery as lithium carbonate from natural brines	Embodiments relate to methods, systems And apparatus tor generating lithium from brine. The brine is heated in a first vessel to greater than 260° C. and CO2 gas is injected mixing with the brine such that the CO2/P is greater than 18 g/atm. The brine is held at greater than 18 g/atm for longer than 20 minutes so that any impurities precipitate as solids leaving only lithium ions and chlorine ions. The brine is moved to a second vessel screening out solid precipitates leaving a brine containing only chlorine and lithium. CO2 gas is injected and mixed with the brine at 260° C. so that the CO2/P is greater than 200 g/atm. The brine is held at greater than 200	2017-10-10	ENERGY, UNITED STATES DEPARTMENT OF	U.S. DEPARTMENT OF ENERGY	NAKANO, JINICHIRO | NAKANO, ANNA | BENNETT, JAMES P.

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			g/atm for longer than 20 minutes suppressing the chlorine as dissolved ions while lithium precipitates out as lithium carbonate. The lithium carbonate precipitate is removed from the brine solution.				
US20210304933A1	2021-09-30	Synthesis of high purity manganese bismuth powder and fabrication of bulk permanent magnet	A synthesis process is disclosed for fabrication of mass quantities of high-purity α-MnBi magnetic powder and subsequent bulk permanent magnet. An illustrative process includes certain steps that include: multiple annealing, multiple comminuting such as multiple ball milling, forming a non-magnetic phase on and/or in the powder particles at particle grain boundaries before particle consolidation such as pressing, and magnetic annealing of a pressed compact. A reproducible and high productive synthesis process is created by combining these steps with other steps, which makes possible production of mass quantities of MnBi powder and bulk magnets with high performance.	2020-12-15	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	TANG, WEI | OUYANG, GAOYUAN | CUI, BAOZHI | CUI, JUN
US20210257620A1	2021-08-19	Binders for silicon electrodes in lithium-ion batteries	An electrode for a lithium-ion electrochemical cell comprises silicon particles and carbon particles coated on a conductive current collector. The silicon and carbon particles being bound to each other and to the current collector by a cross-linked binder formed from a combination of a poly(carboxylic acid) such as poly(acrylic acid) and a branched polyethyleneimine. A method of preparing the anode also is described.	2020-02-14	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	SHI, ZHANGXING | ZHANG, LU
US20200270725A1	2020-08-27	Hard Disk Drive Dismantlement for Critical Material Recovery	A system and method for recycling rare earth materials from dissimilar hard disk drives are provided. The system and method generally include scanning each hard disk drive, sorting and aligning each hard disk drive, rapid fastener removal or diversion to a metrology station, and the collection of separated value streams, optionally for formation into new magnetic stock. For each scanned hard disk drive having a match in an inventory database, the method includes the separation of an internal magnet from residual components. For each scanned hard disk drive lacking a match in the inventory database, the method includes generating a metrology data collection record containing the location of each fastener on multiple surfaces of the corresponding hard disk drive. The system and method are commercially scalable with the potential to generate between 600 and 700 metric tons of rare earth elements from a single processing facility annually, including neodymium for example.	2020-02-25	UT-BATTELLE, LLC	OAK RIDGE ASSOCIATED UNIVERSITIES | UT-BATTELLE, LLC	MCINTYRE, TIMOTHY J. | HARTER, JONATHAN J.
US11230752B2	2022-01-25	Hard disk drive dismantlement for critical material recovery	A system and method for recycling rare earth materials from dissimilar hard disk drives are provided. The system and method generally include scanning each hard disk drive, sorting and aligning each hard disk drive, rapid fastener removal or diversion to a metrology station, and the collection of separated value streams, optionally for formation into new magnetic stock. For each scanned hard disk drive having a match in an inventory database, the method includes the separation of an internal magnet from residual components. For each scanned hard disk drive lacking a match in the inventory database, the method includes generating a metrology data collection record containing the location of each fastener on multiple surfaces of the corresponding hard disk drive. The system and method are commercially scalable with the potential to generate between	2020-02-25	UT-BATTELLE, LLC	OAK RIDGE ASSOCIATED UNIVERSITIES | UT-BATTELLE, LLC	MCINTYRE, TIMOTHY J. | HARTER, JONATHAN J.

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			600 and 700 metric tons of rare earth elements from a single processing facility annually, including neodymium for example.				
US20210226263A1	2021-07-22	Cathode recycling of end-of-life lithium batteries	Disclosed herein are improved methods and devices for recycling lithium cathodes from batteries.	2020-11-02	ALLIANCE FOR SUSTAINABLE ENERGY, LLC	ALLIANCE FOR SUSTAINABLE ENERGY, LLC	PARK, KYUSUNG
US20210226273A1	2021-07-22	Methods for cathode recycling of end-of-life lithium batteries	Disclosed herein are improved methods and devices for recycling lithium cathodes from batteries using a Soxhlet extractor.	2020-11-02	ALLIANCE FOR SUSTAINABLE ENERGY, LLC	ALLIANCE FOR SUSTAINABLE ENERGY, LLC	PARK, KYUSUNG | BURRELL, ANTHONY KEIRAN
US11046991B2	2021-06-29	Rapid preconcentration of viable bacteria using magnetic ionic liquid for PCR amplification and culture-based diagnostics	In this disclosure, transition and rare earth metal-based magnetic ionic liquids (MILs) are successfully prepared in a two-step synthesis and used to extract viable bacteria from a liquid sample. The disclosed MILs are extremely hydrophobic MILs and were insoluble in aqueous solution at 0.01% (v/v). Furthermore, these MILs were miscible in a variety of polar and non-polar organic solvents. Moreover, these MILs possess low viscosity and increased magnetic susceptibility. These MILs possess unique characteristics that can have great potential uses in various chemical applications such as extraction solvents in LLE, liquid electrochromic materials (Co-based MILs), and novel reaction media for organic synthesis.	2018-04-11	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC.	ANDERSON, JARED L. | CLARK, KEVIN D.
US20180100065A1	2018-04-12	Stable immobilized amine sorbents for ree and heavy metal recovery from liquid sources	Materials, methods of making, and methods of using a stable and regenerable immobilized amine sorbents for rare earth element and heavy metal recovery from liquid sources. Embodiments of the invention relate to the novel combination of different polyamines, primarily polyethylenimine Mw=800 (PEI800), and an epoxysilane, namely 2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane (ECTMS), covalently immobilizing the REE and heavy metal-adsorbing amine sites within low cost, porous silica particles.	2017-10-12	UNITED STATES DEPARTMENT OF ENERGY	UNITED STATES DEPARTMENT OF ENERGY	GRAY, MCMAHAN L. | KAIL, BRIAN W. | WILFONG, WALTER C. | WANG, QIUMING
US20180316060A1	2018-11-01	Salts for multivalent ion batteries	Methods for preparing electrolyte salts for alkaline earth metal-ion batteries (e.g., calcium and magnesium ion batteries) are described. The electrolyte salts comprise alkaline earth metal (e.g., Mg or Ca) salts of 3,4-dicyano-2-trifluoromethylimidazole (TDI). The methods comprise contacting TDI with an alkaline earth metal bis(trifluoroacetate) salt in trifluoroacetic acid.	2018-07-02	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	LIAO, CHEN | DZWINIEL, TREVOR L. | PAN, BAOFEI | HAN, SANG-DON | BURRELL, ANTHONY
US10680285B2	2020-06-09	Salts for multivalent ion batteries	Methods for preparing electrolyte salts for alkaline earth metal-ion batteries (e.g., calcium and magnesium ion batteries) are described. The electrolyte salts comprise alkaline earth metal (e.g., Mg or Ca) salts of 3,4-dicyano-2-trifluoromethylimidazole (TDI). The methods comprise contacting TDI with an alkaline earth metal bis(trifluoroacetate) salt in trifluoroacetic acid.	2018-07-02	UCHICAGO ARGONNE, LLC	UCHICAGO ARGONNE, LLC	LIAO, CHEN | DZWINIEL, TREVOR L. | PAN, BAOFEI | HAN, SANG-DON | BURRELL, ANTHONY
US20180223391A1	2018-08-09	Method for recovering target materials from source materials	A single-heating stage method for reclaiming or recovering metals like nickel and vanadium from a petroleum waste byproduct has three steps: melting the petroleum waste byproduct in a reducing atmosphere, generating agglomerated metal in the melted byproduct, and lifting the agglomerated metal to an exposed surface of the melted byproduct. The metal precipitates out of the molten byproduct, agglomerates into a separate portion, and rises to an exposed surface of the melted petroleum	2017-02-09	UNITED STATES DEPARTMENT OF ENERGY	U.S. DEPARTMENT OF ENERGY	BENNETT, JAMES P. | NAKANO, JINICHIRO | NAKANO, ANNA

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			waste byproduct even though the metal may have greater density than the molten petroleum waste byproduct. The original petroleum waste byproduct stratifies into a byproduct remnant and the agglomerated metal disk. The agglomerated metal disk is separable from the byproduct remnant and may be additionally separated into constituent metals in those embodiments with multiple metals in the disk.				
US10323298B2	2019-06-18	Method for recovering target materials from source materials	A single-heating stage method for reclaiming or recovering metals like nickel and vanadium from a petroleum waste byproduct has three steps: melting the petroleum waste byproduct in a reducing atmosphere, generating agglomerated metal in the melted byproduct, and lifting the agglomerated metal to an exposed surface of the melted byproduct. The metal precipitates out of the molten byproduct, agglomerates into a separate portion, and rises to an exposed surface of the melted petroleum waste byproduct even though the metal may have greater density than the molten petroleum waste byproduct. The original petroleum waste byproduct stratifies into a byproduct remnant and the agglomerated metal disk. The agglomerated metal disk is separable from the byproduct remnant and may be additionally separated into constituent metals in those embodiments with multiple metals in the disk.	2017-02-09	UNITED STATES DEPARTMENT OF ENERGY	U.S. DEPARTMENT OF ENERGY	NAKANO, JINICHIRO | NAKANO, ANNA | BENNETT, JAMES P.
US20210268132A1	2021-09-02	Methods of sequestering target elements	Provided herein are methods of sequestering target elements (e.g., rare earth elements and/or radiometals) from a sample, methods of purifying target elements from samples, pharmaceutical compositions comprising target elements, and methods of treating a subject with said pharmaceutical compositions.	2021-02-12	LAWRENCE LIVERMORE NATIONAL SECURITY, LLC | THE PENN STATE UNIVERSITY	THE PENN STATE RESEARCH FOUNDATION	DEBLONDE, GAUTHIER | JIAO, YONGQIN | PARK, DAN MCFARLAND | MATTOCKS, JOSEPH ANTHONY | COTRUVO, JR., JOSEPH ALFRED
US62919933P0	-	Mechanochemical recovery of Co, Li and other constituents from spent lithium-ion batteries	-	2019-04-04	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC	IOWA STATE UNIVERSITY RESEARCH FOUNDATION, INC	OLEKSANDR DOLOTKO | VIKTOR BALEMA | IHOR HLOVA | SHALABH GUPTA | YAROSLAV MUDRYK | VITALIJ K. PECHARSKY
US20210238051A1	2021-08-05	Systems and Methods for Separating Yttrium and Strontium	Systems and methods for separating Y and Sr are provided. The systems and methods provide combinations of solutions, vessels, and/or media that can provide Y solutions of industrially beneficial concentration.	2020-02-03	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	O'HARA, MATTHEW J.
US20210024365A1	2021-01-28	Systems and Methods for Separating Radium from Lead, Bismuth, and Thorium	Systems for separating Ra from a mixture comprising at least Ra, Pb, Bi, and Th are provided. The systems can include: a first vessel housing a first media and Th or Bi; a second vessel in fluid communication with the first vessel, the second vessel housing a second media and Pb; and a third vessel in fluid communication with the second vessel, the third vessel housing a third media and Ra, wherein at least one of the first, second, or third medias are different from the other media.Methods for separating Ra from Pb, Bi, and Th are provided, the methods can include: providing a first mixture comprising Ra, Pb, Bi, and/or Th; providing a system that can include: a first vessel housing a first media; a second vessel in fluid communication with the first vessel, the second vessel housing a second media; and a third vessel in fluid communication with the second vessel,	2020-06-05	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	O'HARA, MATTHEW J.

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			the third vessel housing a third media; and exposing the first mixture to the first media within the first vessel then, through the fluid communication, exposing the first remainder to the second media in the second vessel, then, through fluid communication, exposing the next remainder to the third media in the third vessel, the exposing separating the Th and Bi from the Ra and Pb, and the Ra from the Pb.Methods for separating Ra from being associated with a media are also provided. The methods can include: exposing the Ra and media to a chelating agent to form a mixture comprising the Ra complexed with the chelating agent.				
US62470782P0	-	Method of producing pre-lithiated graphite from recycled li-ion batteries	-	2017-03-13	THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	ANDREW MINOR | GAO LIU | ABRAHAM ANAPOLSKY | JULIAN SABISCH
US62929546P0	-	Cathode recycling of end-of-life lithium batteries	-	2019-11-01	ALLIANCE FOR SUSTAINABLE ENERGY, LLC	ALLIANCE FOR SUSTAINABLE ENERGY, LLC	KYUSUNG PARK
US20190260026A1	2019-08-22	Pyrolytic carbon black composite and method of making the same	A method of recovering carbon black includes the step of providing a carbonaceous source material containing carbon black. The carbonaceous source material is contacted with a sulfonation bath to produce a sulfonated material. The sulfonated material is pyrolyzed to produce a carbon black containing product comprising a glassy carbon matrix phase having carbon black dispersed therein. The pyrolysis can be conducted at a temperature from 1100° C. to 1490° C. A method of making a battery electrode and a lithium ion or sodium ion battery is also disclosed.	2019-05-06	UT-BATTELLE, LLC	UT-BATTELLE, LLC	NASKAR, AMIT K. | PARANTHAMAN, MARIAPPAN PARANS
US10985372B2	2021-04-20	Pyrolytic carbon black composite and method of making the same	A method of recovering carbon black includes the step of providing a carbonaceous source material containing carbon black. The carbonaceous source material is contacted with a sulfonation bath to produce a sulfonated material. The sulfonated material is pyrolyzed to produce a carbon black containing product comprising a glassy carbon matrix phase having carbon black dispersed therein. The pyrolysis can be conducted at a temperature from 1100° C. to 1490° C. A method of making a battery electrode and a lithium ion or sodium ion battery is also disclosed.	2019-05-06	UT-BATTELLE, LLC	UT-BATTELLE, LLC	NASKAR, AMIT K. | PARANTHAMAN, MARIAPPAN PARANS
US20210300799A1	2021-09-30	Electrocatalytic bio-oil and wastewater treatment	An anode, a flow cell including the anode, and a method for electrocatalytic treatment of bio-oil and/or wastewater are disclosed. The anode comprises RuO2 particles on a titanium support. The method includes flowing a process stream through the flow cell in the absence of added hydrogen, at a temperature of 0° C. to 50° C. and atmospheric pressure, and applying a potential across the flow cell such that the anode is positive with respect to the cathode, thereby electrocatalytically oxidizing compounds in the process stream to produce a treated process stream at the anode and generating hydrogen gas as a byproduct at the cathode.	2021-03-26	BATTELLE MEMORIAL INSTITUTE	BATTELLE MEMORIAL INSTITUTE	LOPEZ-RUIZ, JUAN A. | EGBERT, JONATHAN D. | FREEMAN, CHARLES J. | GUTIÉRREZ TINOCO, OLIVER Y. | HOLLADAY, JAMELYN D. | HOWE, DANIEL T. | QIU, YANG | RODRIGUEZ PEREZ, ISMAEL A.

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US20200176573A1	2020-06-04	Electrodes for making nanocarbon-infused metals and alloys	A method for preparing a covetic, nanocarbon-infused, metal composite material is described is herein. The method comprises heating a stirring molten mixture of a metal (e.g., Cu, Al, Ag, Au, Fe, Ni, Pt, Sn, Pb, Zn, Si, and the like) and carbon (e.g., graphite) at a temperature sufficient to maintain the mixture in the molten state in a reactor vessel, while passing an electric current through the molten mixture via at least two spaced electrodes submerged or partially submerged in the molten metal. Each of the electrodes has an electrical conductivity that is at least about 50 percent of the electrical conductivity of the molten mixture at the temperature of the molten mixture. Preferably, the conductivity of the electrodes is equal to or greater than the conductivity of the molten mixture.	2018-12-04	BALACHANDRAN, UTHAMALINGAM | DORRIS, STEPHEN E. | MA, BEIHAI | LEE, TAE H. | FORREST, DAVID R. | KLINGSHIRN, CHRISTOPHER	U.S. DEPARTMENT OF ENERGY	BALACHANDRAN, UTHAMALINGAM | DORRIS, STEPHEN E. | MA, BEIHAI | LEE, TAE H. | FORREST, DAVID R. | KLINGSHIRN, CHRISTOPHER
US20210351427A1	2021-11-11	Z-Scheme Microbial Photoelectrochemical System (MPS) for Wastewater-to-Chemical Fuel Conversion	A wastewater to chemical fuel conversion device is provided that includes a housing having a first chamber and a second chamber, where the first chamber includes a bio-photoanode, where the second chamber includes a photocathode, where a backside of the bio-photoanode abuts a first side of a planatized fluorine doped tin oxide (FTO) glass, where a backside of the photocathode abuts a second side of the FTO glass, where a proton exchange membrane separates the first chamber from the second chamber, where the first chamber includes a wastewater input and a reclaimed water output, where the second chamber includes a solar light input and a H2 gas output, where the solar light input is disposed for solar light illumination of the first chamber and the second chamber.	2020-05-06	LI, YAT	THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	LI, YAT

NETL PATENTS

Publication Number	Publication Date	Title	Abstract	Inventor Name
USPN11170986	11/9/2021	Luminescence Based Fiber Optic Probe for the Detection of Rare Earth Elements	his invention describes a portable luminescence-based fiber optic sensor for the detection and quantification of REEs in coal by-product waste streams. The device provides rapid results, with a lower limit of detection in the parts per-billion, for terbium, europium, dysprosium, and samarium. The device can be used with luminescence sensitizers to lower the limit of detection for the quantification of additional REEs. The rapid response time provided by the device can save the end user costs associated with inactivity during recovery or mining operations while potentially allowing for in line monitoring or rapid field sampling. Compared to conventionally used technology such as inductively coupled plasma-mass spectrometry, the novel sensor represents a more affordable, compact, and field ready option for REE detection.	John Baltrus, Paul Ohodnicki, John Ahern, Jacob (Zsolt) Poole
USPN10323125	6/18/2019	Polymer for Carbon Dioxide Capture and Separation	This invention describes the design, synthesis, and use of a new polymeric sorbent (polybenzimidazole, BILP-101) for CO2 capture and separation from mixed gas streams. The polymer is synthesized using a template-free polycondensation reaction between commercially available aryl aldehyde and amine-based monomers. Evaluation of BLIP-101 under realistic test conditions demonstrated a sorbent material with exceptional CO2 uptake/working capacity, high CO2 selectivity, as well as superior chemical and thermal stability. The simplified fabrication process will allow for easier commercial scale up at an overall lower production cost. Furthermore, while the neat BILP-101 is a strong physical sorbent, reactivity of the material can be tuned for stronger interaction with CO2 as a chemical sorbent. Possible applications for this technology may include CO2 capture from fossil fueled power plants, natural gas sweetening, biogas updgrading, and CO2 removal from cabin air for life support systems.	David Hopkinson, Ali Sekizkardes
USPN10358694	7/23/2019	System and Method for Concentrating Rare Earth Elements from Coal Byproducts/Slag	NETL researchers have developed a novel method that concentrates REEs from coal byproducts, such as ash and slag, to facilitate extraction, expanding the possibilities for a domestic supply of REEs. A high concentration of REEs is achieved by partitioning the elements into a single solid compound through temperature/time manipulations without acid leaching. Using this method, REEs of less than 0.05% – or 500 parts per million – could be concentrated to 59%. The process begins by fluxing a coal byproduct with predetermined additives in air and heating it at elevated temperatures until molten. Then, the melt is slowly cooled at a controlled rate. The controlled cooling forces the REE-bearing phase to precipitate as solid from the melt. During this stage, essentially all REEs are concentrated in this solid and separated from the melt. Cooling can be controlled to co-precipitate other minerals at large quantities along with the REE-bearing phase, if desired; byproduct credits would expand economic benefits.	Jinichiro Nakano, Anna Nakano, James P. Bennett
Filed 08/12/2019	N/A	Selective Material Recovery from Natural Brines	Geothermal brines are hydrothermal fluids naturally heated under the earth's surface and are a known source of environmentally sustainable, renewable energy. Additionally, these brines can exhibit significant concentrations of valuable minerals and critical metals. Most brines in the United States tend to contain relatively high Li content, as well as REEs. Li is used in advanced clean energy technologies, including fuel cells, electric vehicles and renewable energy applications. Because of its importance in energy storage devices, Li has been identified as a near-critical material (second-highest ranking) in the U.S. DOE 2011 Critical Materials Strategy. Seventeen elements in the periodic table are considered REEs (including scandium and yttrium). Rare earths are highly valuable because they are essential components of modern technological devices, such as cell phones and computer hard drives. They are also used in advanced technologies that support a broad range of industries, including health care, transportation and defense. The technology advanced by NETL uses carbon dioxide (CO2) as the only additive. The mixture is held at necessary pressure and temperature levels so that undesired impurities in the brine precipitate as solids, leaving a secondary brine substantially comprising the targeted materials. NETL research enabled discoveries of required thermodynamic domains where targeted materials are stable or unstable. This makes possible high recovery rates of REEs and Li through control of CO2 and pressure parameters in relatively small footprint and in an environmentally benign fashion.	Jinichiro Nakano, Anna Nakano, James P. Bennett
Filed 07/15/2021	N/A	Step-leaching Process of Rare Earth Elements from Ash Materials Using Mild Inorganic Acids at Ambient Conditions	This invention describes a method to extract REE from select coal combustion fly ashes using mild inorganic acids at ambient temperatures via a three-step mild acid extraction process that results in high levels of extraction (ranging from 80-100%).	Mengling Stuckman, Christina Lopano, Thomas Tarka
USPN10315926	6/11/2019	Selective Lithium Recovery as Lithium Carbonate from Natural Brines	This invention describes a two-step process for the extraction of Li from natural brines; directly generating Li2CO3, an industrially useful product. The method uses a unique carbon pressure-based process parameter to first concentrate Li as ions in the brine solution; followed by the extraction of Li as Li2CO3 through the application of CO2 gas to the concentrated brine under predetermined conditions. The proposed approach is a combination of simple concepts, and can be implemented using existing geothermal technologies. The source of CO2 used in the separation process can be waste gas from other industrial processes generating CO2. This novel process significantly reduces the overall cost, time, and energy demand for Li extraction from geothermal brines while reducing CO2 emissions.	Jinichiro Nakano, Anna Nakano, James P. Bennett
USPN10323298	6/18/2019	Method for Recovering Target Materials from Source Materials	This invention describes a single-stage process for the extraction of Ni and V from petroleum waste byproducts. The novel process represents a simplified and more environmentally friendly approach for the high yield and high purity extraction of Ni and V. Using this process, Ni and V are both 'lifted' above the waste matrix surface, making subsequent separation easier using simple beneficiation processes such as magnetic and gravity techniques; minimizing or eliminating the need for leaching, crushing, and grinding stages.	Jinichiro Nakano, Anna Nakano, James P. Bennett

SEARCH TERMS

TA:(Aluminum OR bauxite OR antimony OR arsenic OR barite OR beryllium OR bismuth OR cesium OR chromium OR cobalt OR fluorspar OR gallium OR germanium OR graphite OR hafnium OR helium OR indium OR lithium OR magnesium OR manganese OR niobium OR platinum group metals OR potash OR "rare earth" OR rhenium OR rubidium OR scandium OR strontium OR tantalum OR tellurium OR tin OR titanium OR tungsten OR uranium OR vanadium OR zirconium) AND ((ALL_AN:("Ames National Laboratory" OR "Iowa State University" OR TREE@"IOWA STATE UNIVERSITY") OR ALL_AN:("Argonne National Laboratory" OR "Uchicago Argonne" OR TREE@"UCHICAGO ARGONNE" OR TREE@"ARGONNE NAT LABUNIV OF CHICAGO DEVMENT") OR ALL_AN:("Brookhaven National Laboratory" OR "Brookhaven Science Associates" OR TREE@"BROOKHAVEN NAT LAB") OR ALL_AN:("Fermi National Accelerator Laboratory" OR "Fermi Research Alliance" OR TREE@"FERMI RESEARCH ALLIANCE LLC") OR ALL_AN:("Frederick National Laboratory" OR " Leidos Biomedical Research" OR TREE@"LEIDOS BIOMEDICAL RES") OR ALL_AN:("Idaho National Laboratory" OR TREE@"BATTELLE ENERGY ALLIANCE") OR ALL_AN:("Lawrence Berkeley National Laboratory" OR TREE@"LAWRENCE BERKELEY NAT LAB" OR TREE@"THE REGENTS OF THE UNIVERSITY OF CALIFORNIA") OR ALL_AN:("Lawrence Livermore National Laboratory" OR TREE@"Lawrence Livermore National Security LLC") OR ALL_AN:("Los Alamos National Laboratory" OR TREE@"TRIAD NAT SECURITY LLC") OR ALL_AN:("National Energy Technology Laboratory" OR TREE@"NAT ENERGY TECH LAB" OR TREE@"United States National Nuclear Security Administration" OR TREE@"DEPARTMENT OF ENERGY") OR ALL_AN:("National Renewable Energy Laboratory" OR TREE@"ALLIANCE FOR SUSTAINABLE ENERGY") OR ALL_AN:(Oak Ridge National Laboratory OR TREE@"OAK RIDGE NAT LAB" OR TREE@"UT BATTELLE LLC")) OR (ALL_AN:("Pacific Northwest National Laboratory" OR TREE@"BATTELLE MEMORIAL INST") OR ALL_AN:("Princeton Plasma Physics Laboratory" OR TREE@"PRINCETON UNIVERSITY") OR ALL_AN:("Sandia National Laboratory" OR TREE@"NAT TECH & ENG SOLUTIONS OF SANDIA LLC") OR ALL_AN:("SLAC National Accelerator Laboratory" OR TREE@"Stanford Management Co.") OR ALL_AN:("Thomas Jefferson National Accelerator Laboratory" OR TREE@"JEFFERSON SCI ASSOCS LLC"))) AND TAC:(recycl* OR reus* OR reprocess* OR reclaim* OR recover* OR salvag*)

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Terms: "Rare Earth" "Critical Material" "Critical Mineral"