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Critical Challenges. Practical Solutions.

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Energy & Environmental Research Center (EERC)

CRITICAL MINERALS: WHAT, HOW, WHY ALL THE HYPE?

September 21, 2022

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

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AN ALLETE COMPANY

Minnkota Power COOPERATIVE
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Industrial Commission of North Dakota
Lignite Resarch, Development and
Marketing Program

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PRESENTERS

John Kay, Principal Engineer
Emissions and Carbon Capture, EERC

Bruce Folkedahl, Senior Research Engineer
Critical Materials, EERC

Ryan Ellison
Director of Business Development and IR
Dakota Lithium

Critical Minerals Play a Vital Role in Our Modern Economy and National Security

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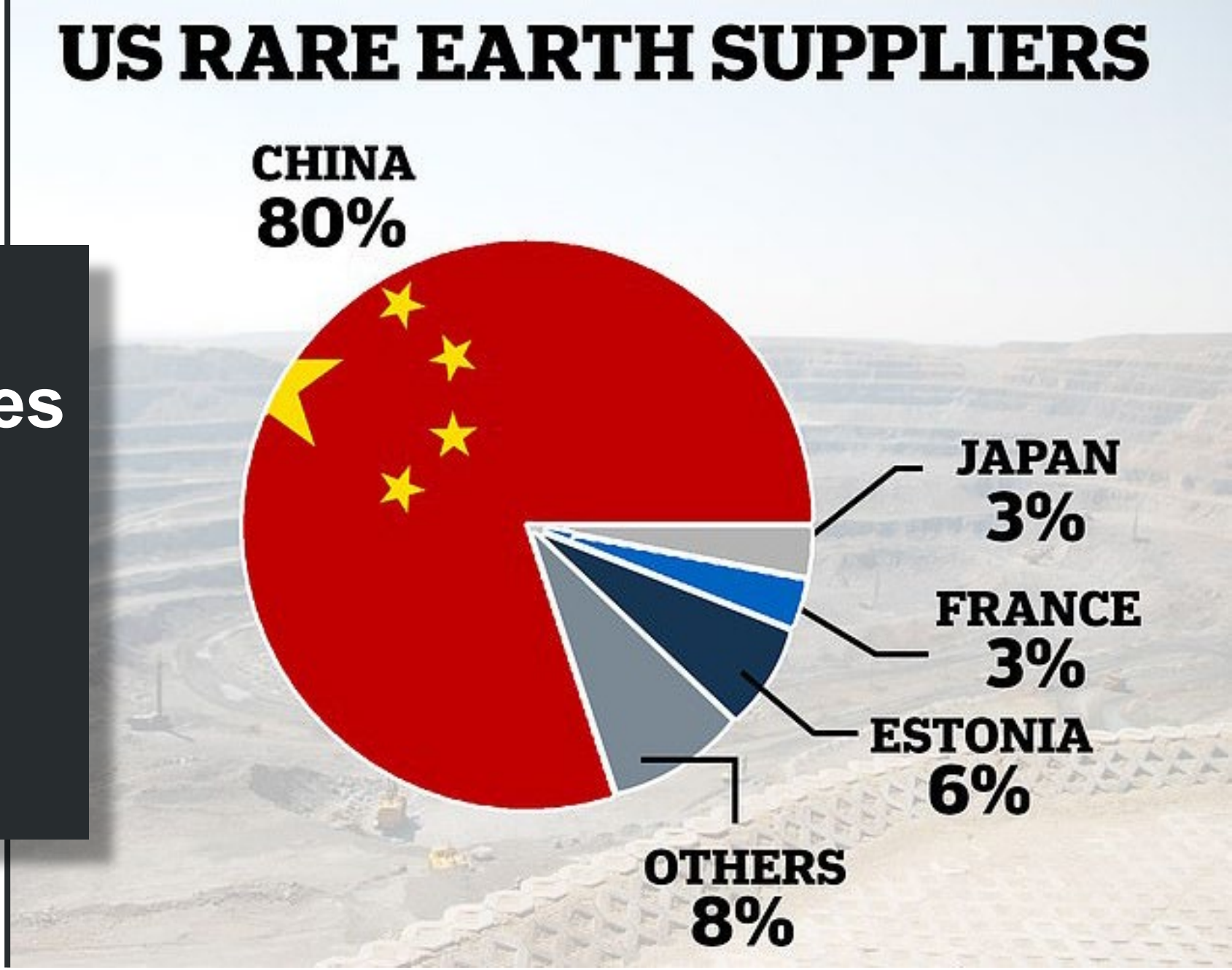
The United States is more than 80% reliant on imports.



We Are in a Unique Position to Be at the Forefront of a Nascent Industry

Factors that position us for success:

1. Reputation and research expertise.
2. Mining and processing experience.
3. Unparalleled lignite coal resources and energy development.
4. State governments supportive of natural resource development.
5. Basinwide collaborations will provide expertise to answer key research questions.

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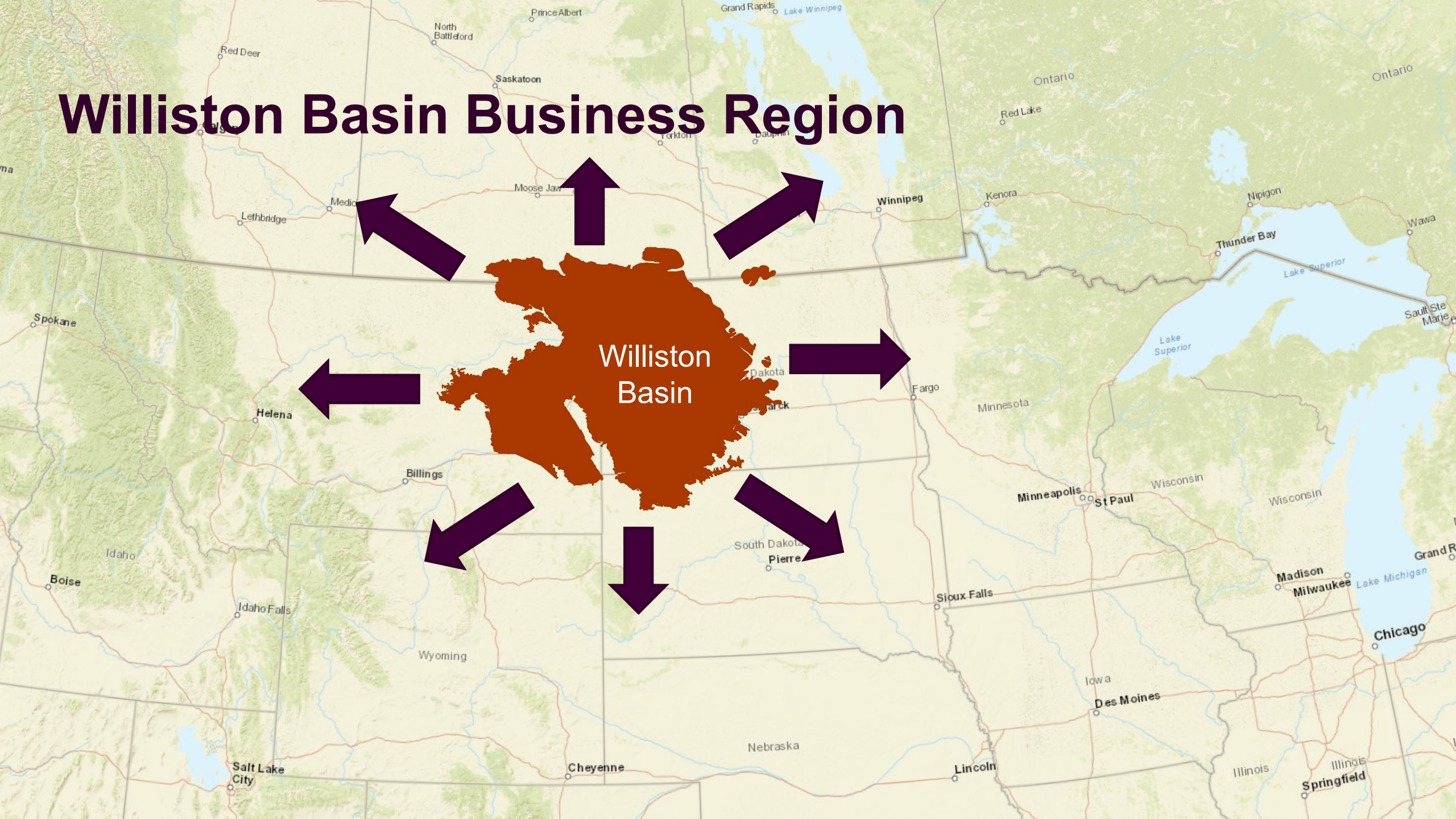
Williston Basin Business Region



Webinar Series Events

Critical Minerals: What, How, Why All the Hype?
September 21, 2022

Today's Critical Mineral Technologies and How to Move Forward
November 30, 2022

Why Do Critical Mineral Business in the Williston Basin?
Our Strengths, Our Assets, Our Needs
January 11, 2023

COMING SOON

Securing the Williston Basin's Critical Mineral Future:
Findings and Next Steps
March 2023

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BRUCE FOLKEDAHL

Senior Research Engineer, Critical Materials
Energy & Environmental Research Center
University of North Dakota

Defining Critical Minerals

Critical Minerals

Essential to our modern economy and national security.

Have a supply chain that is vulnerable to disruption.

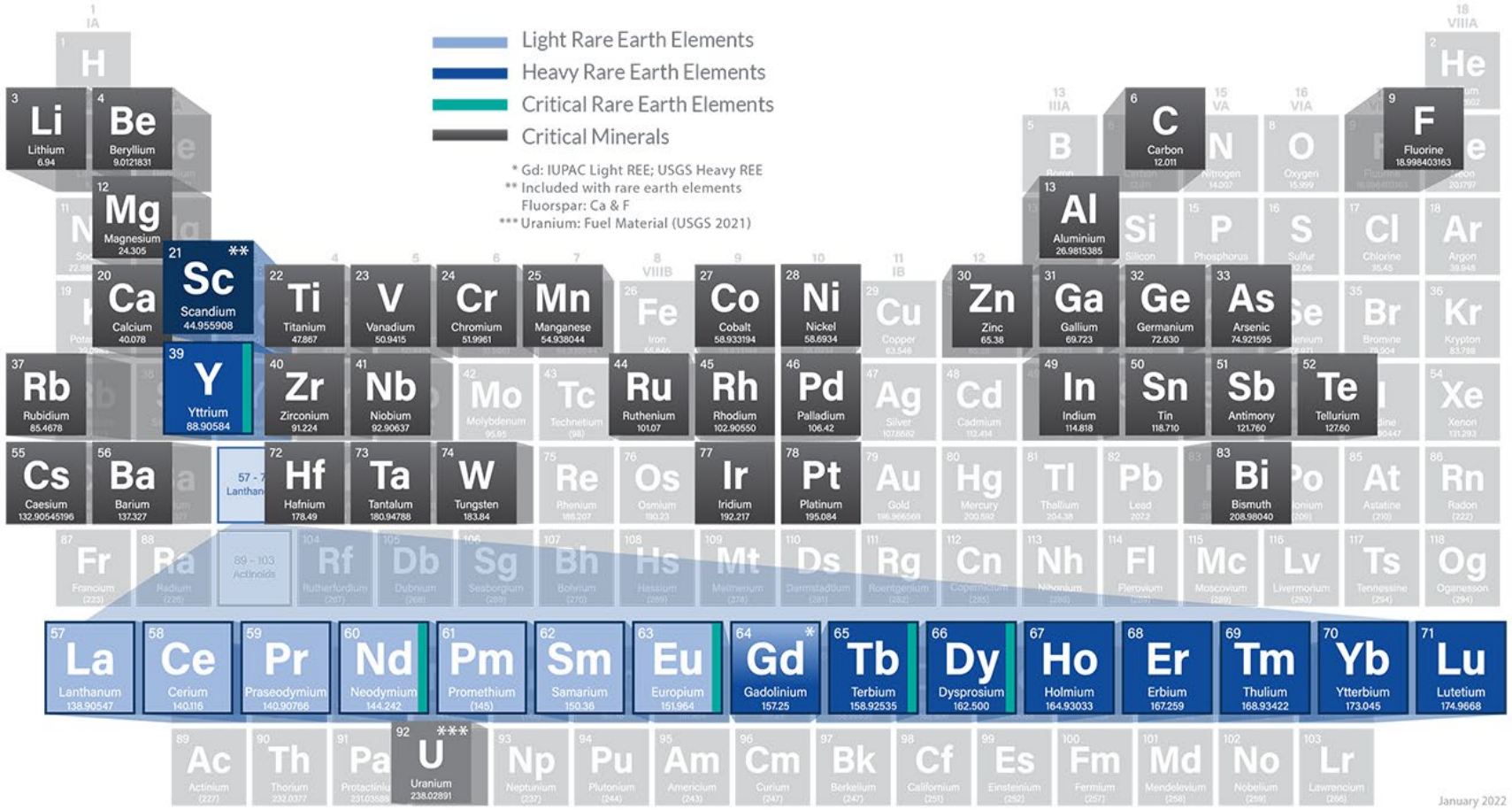
Rare-Earth Elements (REEs)

- Not rare but found together.
- Chemically similar and difficult to separate.

Critical Minerals (CMs)

- Catch-all term for the critical minerals that are not REEs.
- No other common factor.

What Are the CMs?



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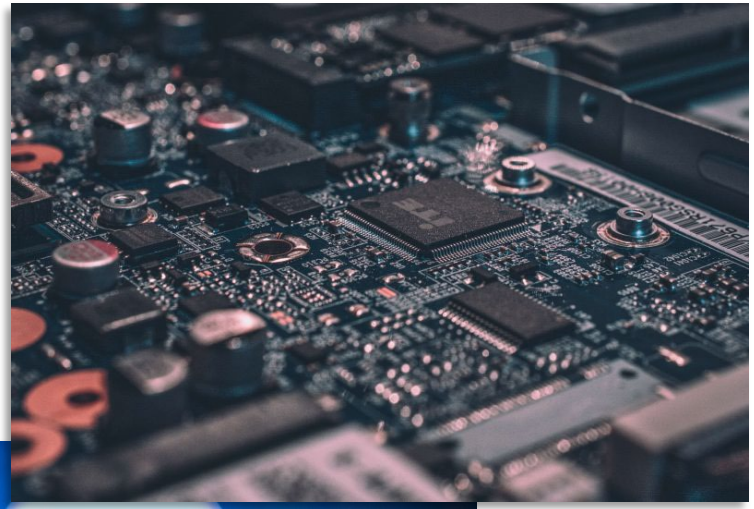
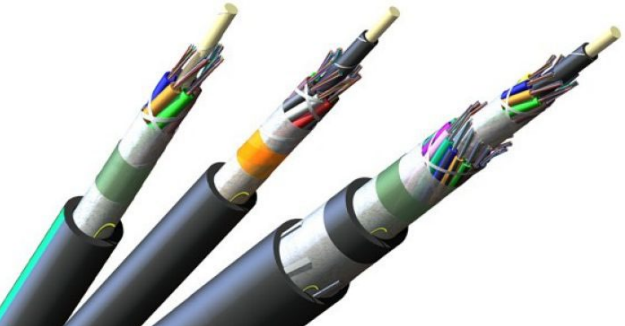
CMs in the Electronics Industry

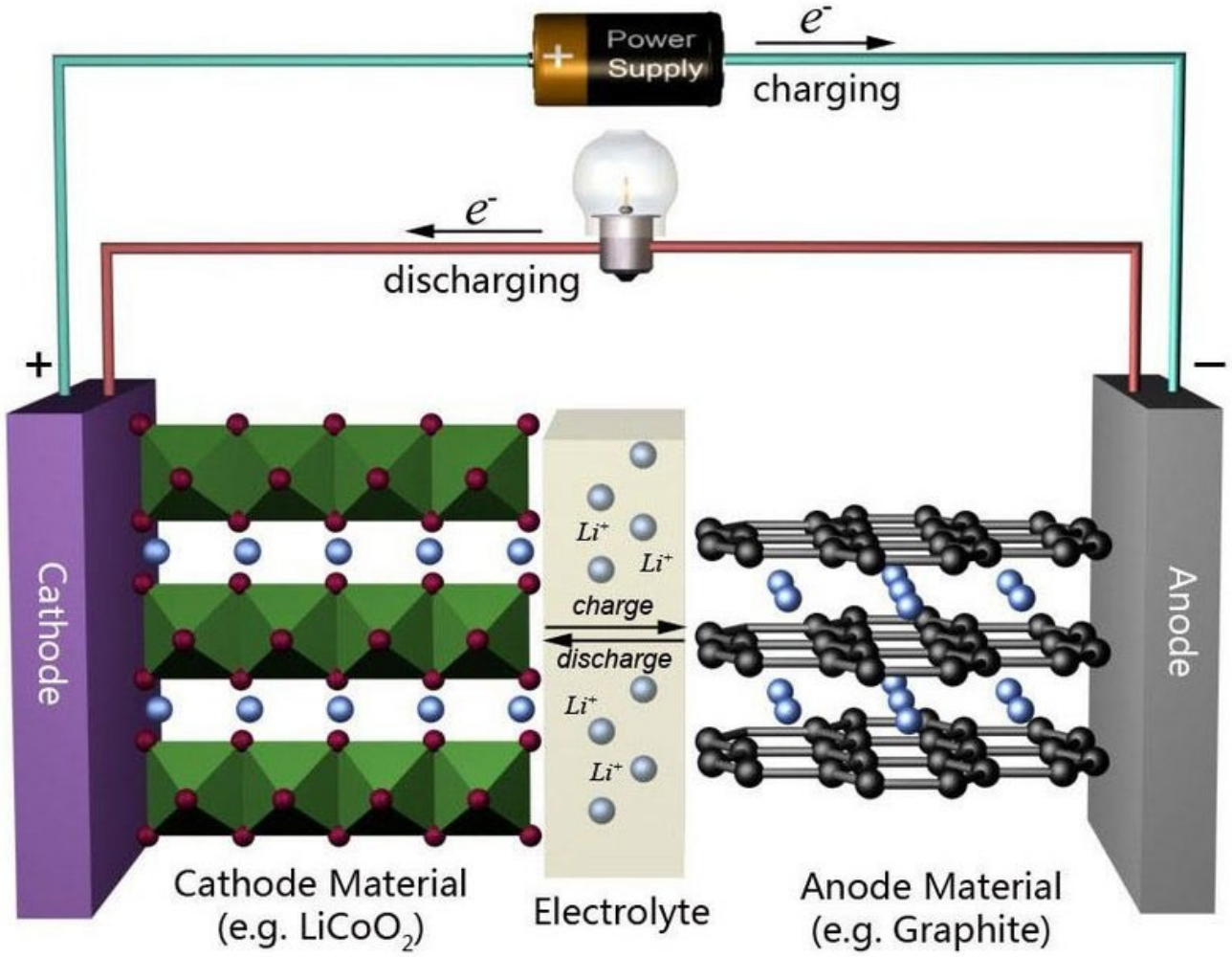
- Transistors
- Solar cells
- LEDs
- Lasers
- Fiber optics





United States has no domestic source of two elements critical to electronics manufacturing: gallium and germanium.

Lithium-Ion Battery Materials



- CMs in batteries of all sizes, from hearing aid to grid scale: lithium, cobalt, manganese, nickel, and graphite.
- Heavy growth in all elements with electric vehicle (EV) industry and possible grid-scale energy storage.
- Doubling every 3–5 years.

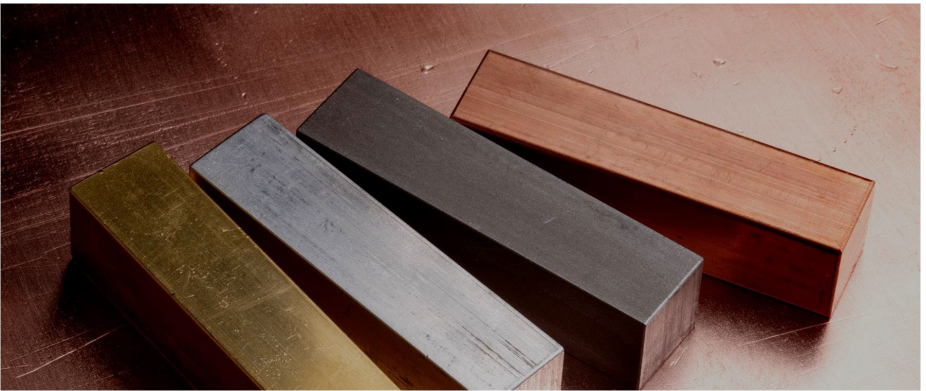
Ultrarare Precious Metals: The Platinum Group

Uses

- Catalysts (catalytic converters in cars).
- Electrolysis for hydrogen.
- Other small, nonreplaceable applications in industry, medicine, and electronics.
- Investment metals—all over $1000 per ounce.

Platinum group metals are more abundant in meteorites than rock ores.

- Six metals that occur together.
- Five are CMs: platinum, palladium, iridium, rhodium, and ruthenium.
- South African mines produce more that 60% of the global platinum group metals market.



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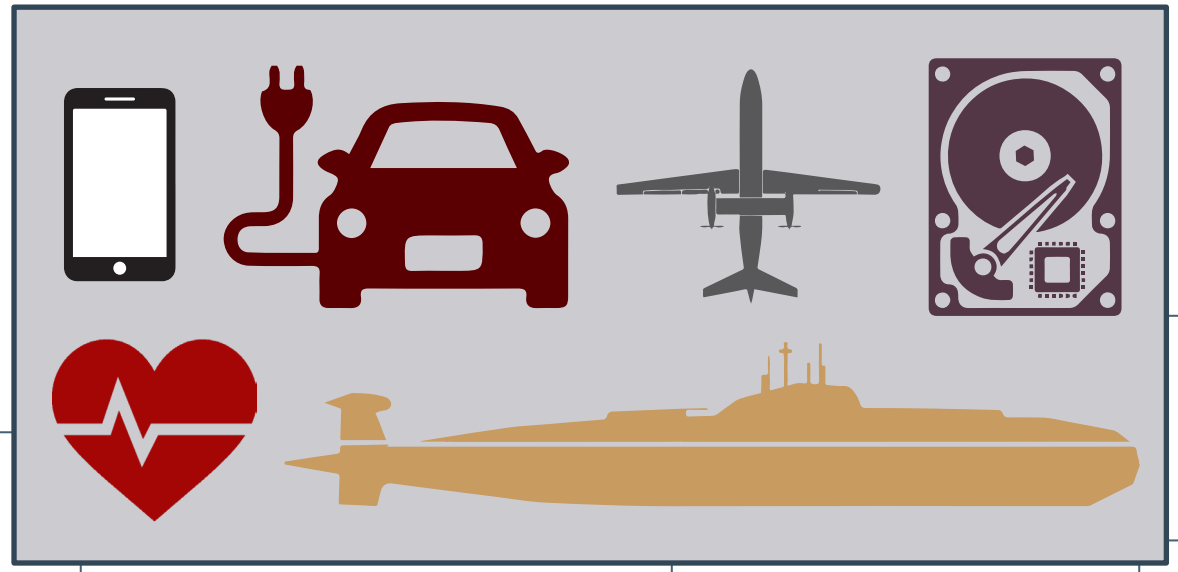
REEs: The United States Is More than 80% Reliant on Imports

Phosphors
Eu, Y, Tb, Nd, Er,
Gd (Ce, Pr)
Cathode Ray Tubes
LCD Lighting
Fluorescent Lighting
Medical Imaging
Lasers
Fiber Optics

Magnets
Nd, Pr (Tb, Dy)
Motors
Disk Drives
MRI
Power Generation
Microphones and Speakers

Defense
Nd, Pr, Dy, Tb, Eu, Y,
La, Lu, Sc, Sm



Metallurgical Alloys
Nickel–Metal–Hydride
Batteries
Fuel Cells
Steel
Lighter Flints
Super Alloys
Aluminum/Magnesium

Catalysts
La, Ce (Pr, Nd)
Petroleum Refining
Catalytic Converter
Diesel Additives
Chemical Processing
Industrial Pollution
Scrubber

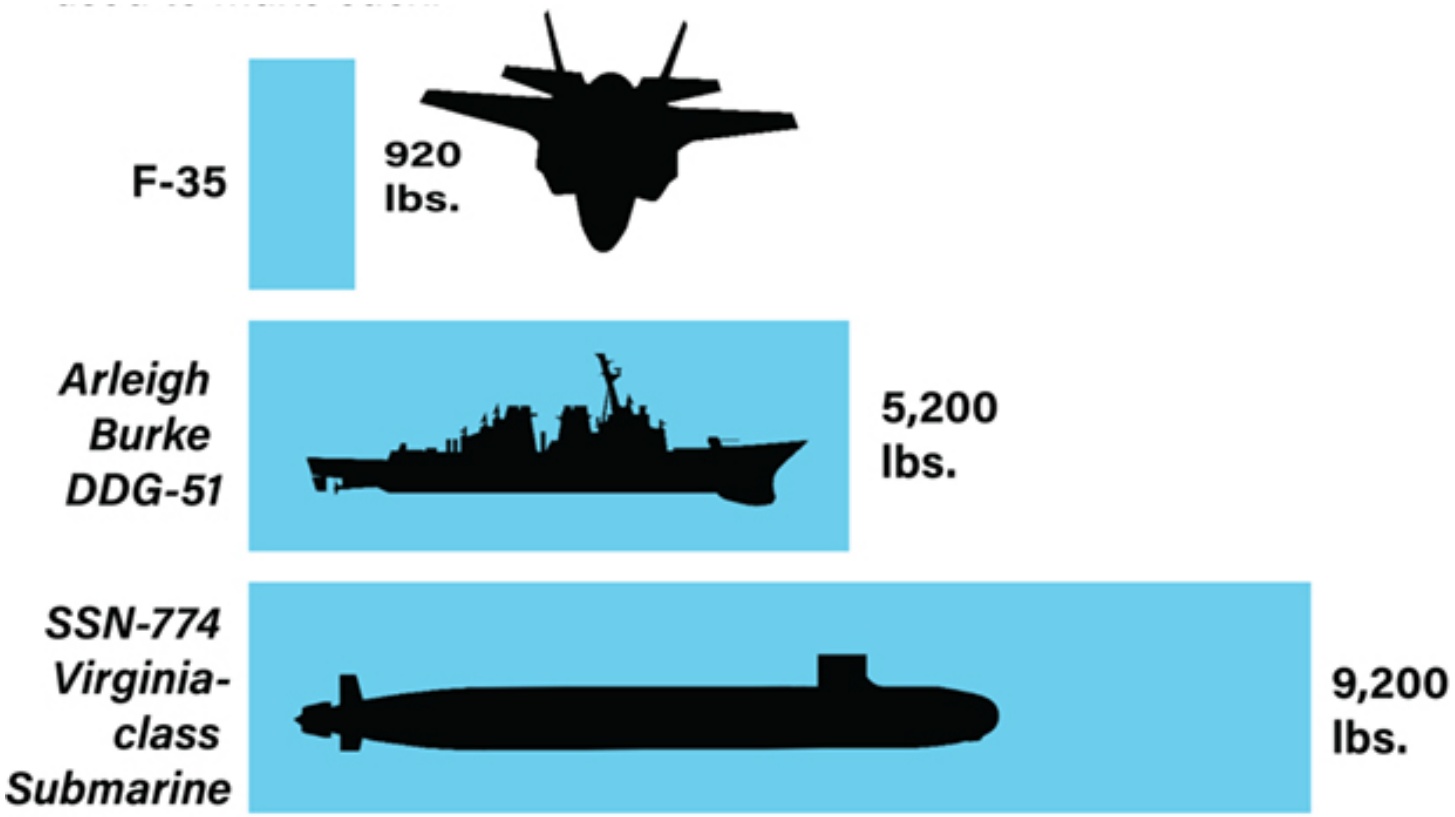
Glasses and Polishing
Ce, La, Pr, Nd, Gd, Er, Ho
Polishing Compounds
Decolorizers/Colorizers
UV-Resistant Glass
X-Ray Imaging

Other
Water Treatment
Pigments (Ce, Y)
Fertilizers

Ceramics
La, Ce, Pr, Nd, Y
Eu, Gd, Lu, Dy
Capacitors
Sensors
Colorants
Scintillators
Refractories

REEs and National Security

Amount of REEs to Produce One Military Vehicle



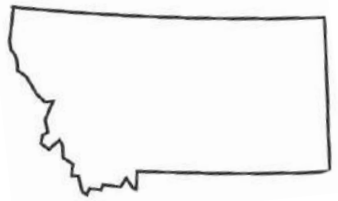
Source: Congressional Research Service

What resources do we have?

What Has North Dakota to Offer?

- World's largest lignite deposit: 350 billion tons.
- Best identified coal seams.
- Some have high REE concentrations.
- The Harmon–Hanson coal seam in North Dakota has the potential to hold significant quantities of REEs.

What Has Montana to Offer?



- Less characterized coal seams.
- Montana Tech's work on mapping coal seams has been a valuable source.

Photo by Marguerite, from Flickr

What Has South Dakota to Offer?

- No active coal mines.
- Needs characterization.
- Sample collection is planned.

Other Domestic REE Sources

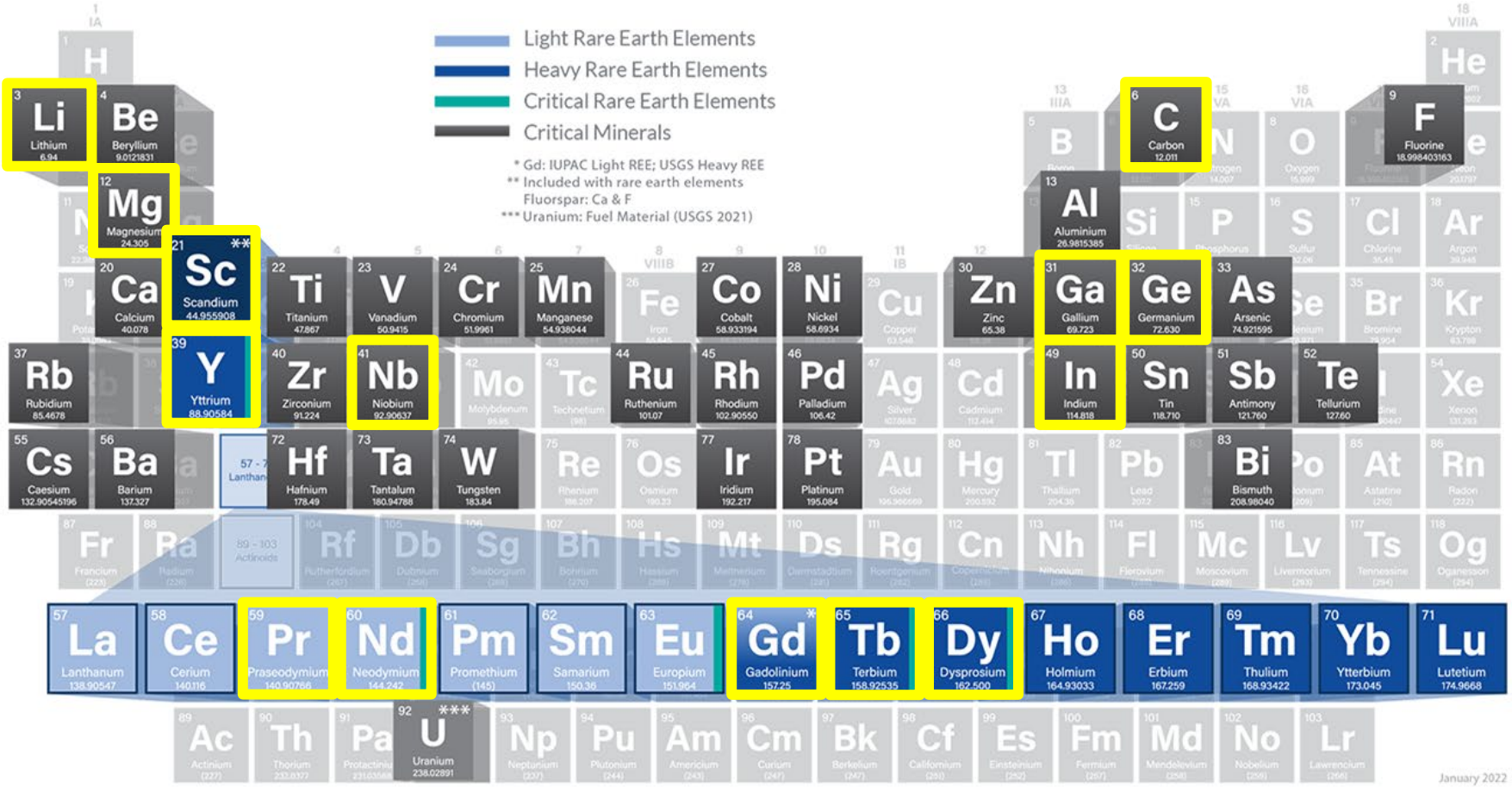
Unintended production of REEs associated with U.S. coal mining potentially exceeds 40,000 tons annually.

Of that, heavy REEs may exceed 10,000 tons annually.*

The U.S. uses approximately 6000 tons annually.

* Ackman, T.; Ekmann, J.; Kirchner, C.; Lopert, E.; Pierre, J. Rare Earth Elements in Coal – The Case for Research and Development into Co-Production with Coal. Leonardo Technologies, Inc., 2012.

Elements with Greatest Potential to Contribute to the Williston Basin Market



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Developing New Sources and Innovative Ways to Extract CMs and REEs

Existing Lignite Coal Mines

Produced Water

ND Shales: Pierre, Niobrara, Upper and Lower Bakken

Deep Unminable Coal Seams by In Situ Extraction

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Coal Mining and CM Recovery Synergy

- Mining costs
- Transportation costs
- Processing costs: crushing and grinding

Potential for value-added recovery of CMs

Opportunity for the Williston Basin

Current

Mining Operations → Separation → Intermediary Form → Metal → Alloy → Consumer Goods

Generally Outside the United States

Limited U.S. Production

Inside the United States for Specific Applications

Possible Future

Mining Operations → Separation → Intermediary Form → Metal → Alloy → Consumer Goods

Conducted in the Williston Basin Region

Expanded U.S. Production

Inside the United States for Specific Applications

RYAN ELLISON

Founder, Director of Investor Relations and Business Development
Dakota Lithium

DAKOTA LITHIUM

[redacted]

CONSUMER PRODUCTS – DAKOTA LITHIUM

200%	1/2	5X	4X	100%
TWICE THE POWER OF TRADITIONAL BATTERIES	HALF THE WEIGHT	CHARGES UP TO 5X FASTER	LASTS 4X AS LONG	SAFE & RELIABLE

Vision for the lithium-battery supply chain by 2030, the United States and its partners will establish a secure battery materials and technology supply chain that supports long-term U.S. economic competitiveness and equitable job creation, enables decarbonization, advances social justice, and meets national security requirements.

NATIONAL BLUEPRINT FOR LITHIUM BATTERIES
2021–2030

Battery development and production are strategically important for the United States, both as part of the transition to a clean energy economy and as a key element of the competitiveness of the automotive industry.

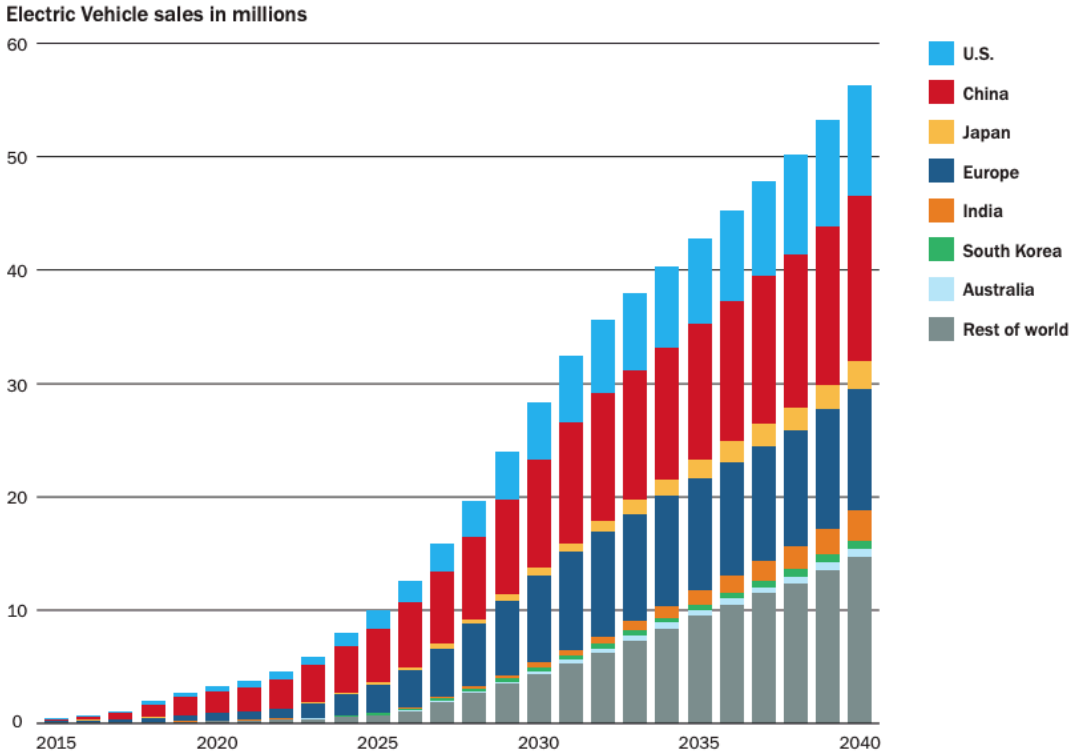


FIGURE 1. Annual Sales of Passenger EVs (Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs)).
Source: BloombergNEF Long-Term Electric Vehicle Outlook 2019.[16]

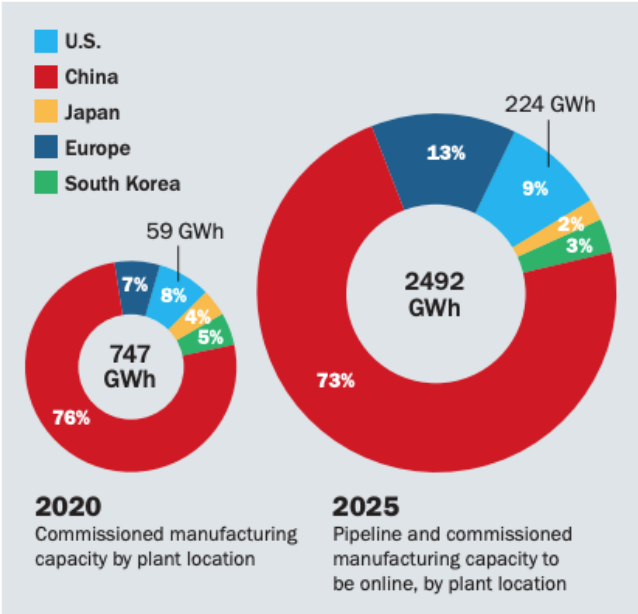
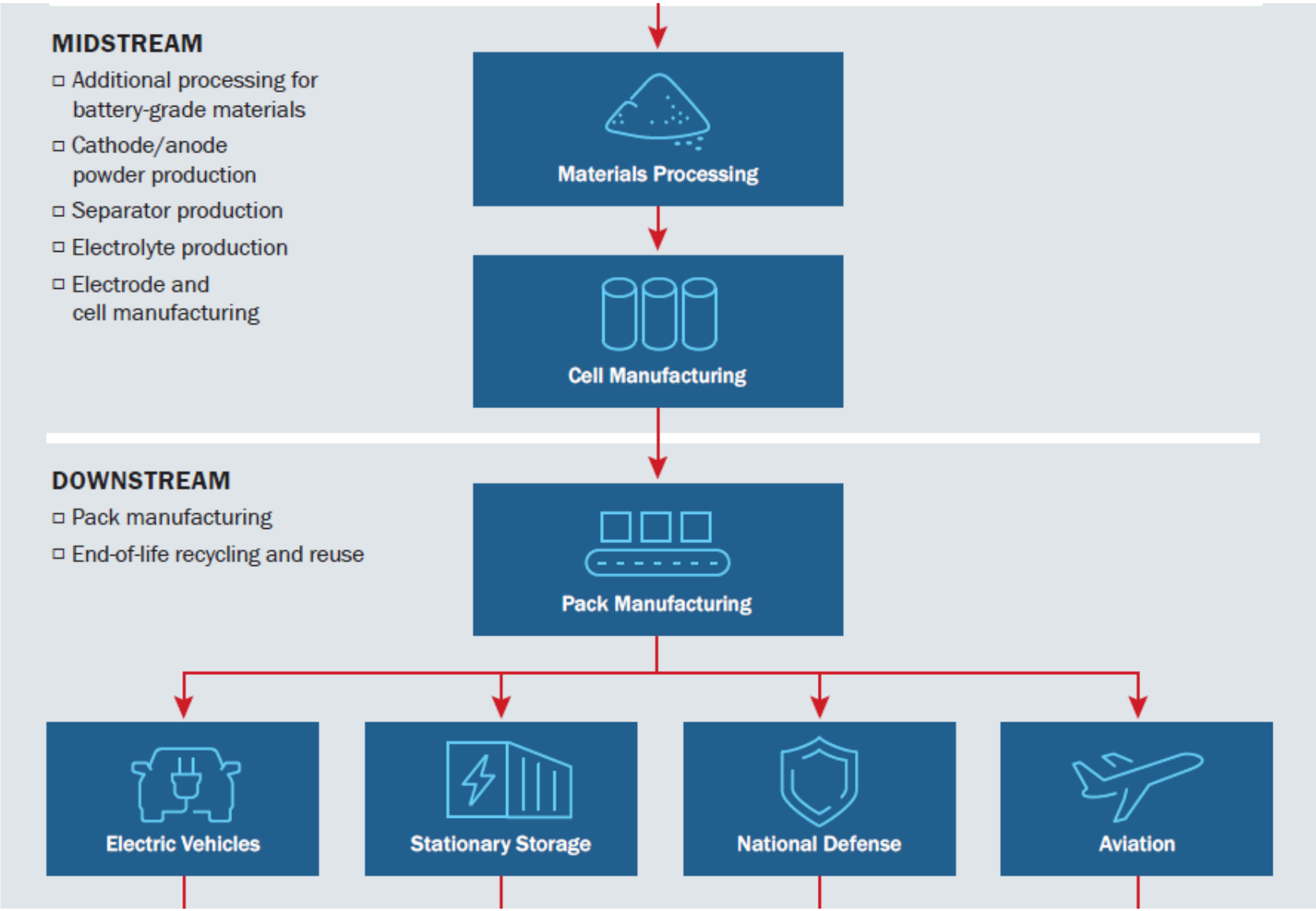


FIGURE 3. Cell manufacturing capacities.
Source: "Lithium-Ion Battery Megafactory Assessment", Benchmark Mineral Intelligence, March 2021.


MIDSTREAM
Additional processing for battery-grade materials
Cathode/anode powder production
Separator production
Electrolyte production
Electrode and cell manufacturing
Materials Processing
Cell Manufacturing
DOWNSTREAM
Pack manufacturing
End-of-life recycling and reuse
Pack Manufacturing
Electric Vehicles
Stationary Storage
National Defense
Aviation

MISSING LINK – BATTERY CATHODE MANUFACTURING

Country	Cathodes Manufacturing (3 M tons)	Anode Manufacturing (1.2 M tons)	Electrolyte Solution Manufacturing (339,000 tons)	Separator Manufacturing (1,987 M sq. m)
United States	—	10%	2%	6%
China	42%	65%	65%	43%
Japan	33%	19%	12%	21%
Korea	15%	6%	4%	28%
Rest of World	10%	—	17%	2%

Source: BloombergNEF, Battery Components Manufacturing Asset Map 2019, Accessed March 15, 2021.

Source: FCAB National Blueprint Lithium Batteries June 2021, pg 19

Carbon Ore, Rare Earth, and Critical Minerals Initiative (CORE-CM)

U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL)-Led Program

- Catalyze economic growth.
- Job creation in energy communities.
- Energy communities not to be left behind.
- Domestic production of REEs and CMs.
- Strengthen our national economy and security.

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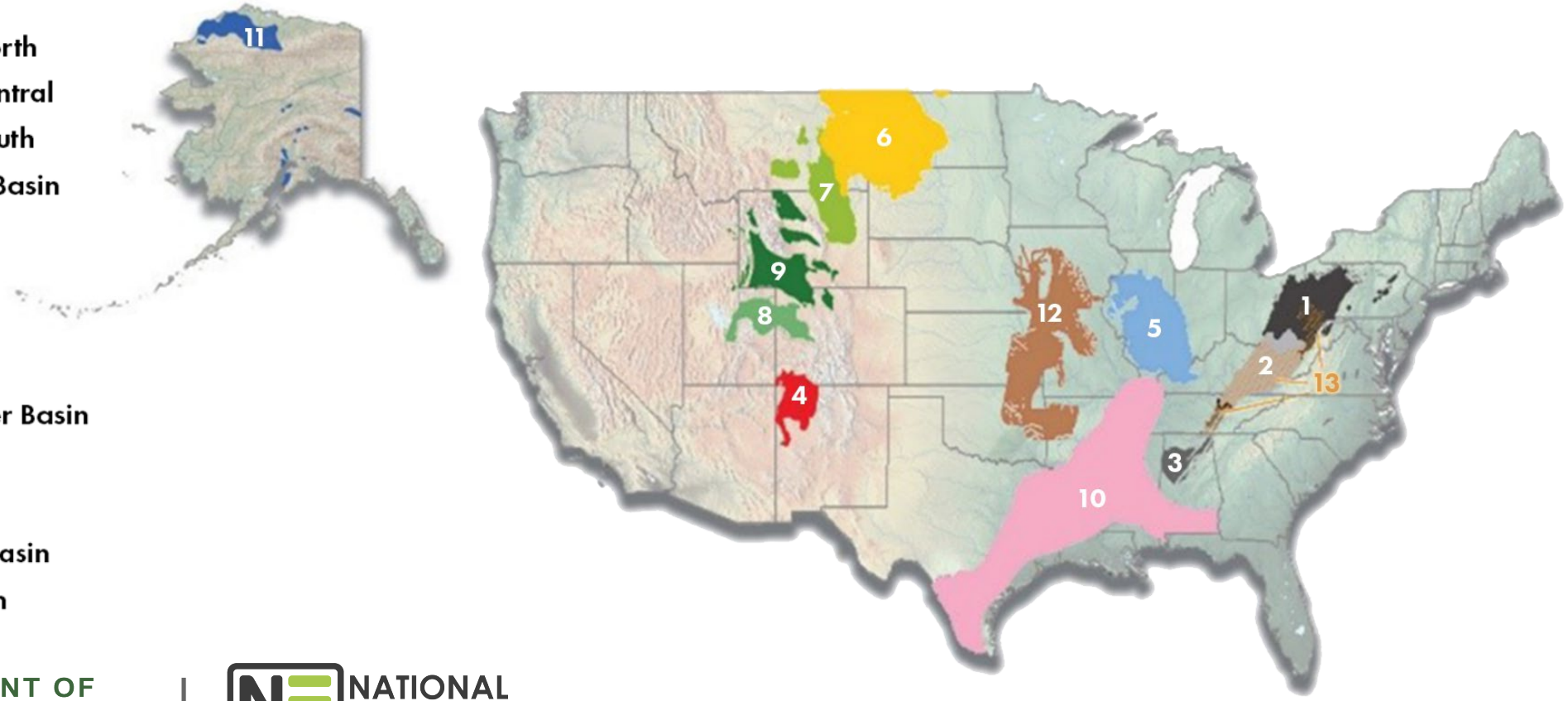
13 CORE-CM Initiative Teams

US BASINS

- 1 Appalachian Basin, North
- 2 Appalachian Basin, Central
- 3 Appalachian Basin, South
- 4 San Juan River-Raton Basin
- 5 Illinois Basin
- 6 Williston Basin
- 7 Powder River Basin
- 8 Uinta Basin
- 9 Green River-Wind River Basin
- 10 Gulf Coast Basin
- 11 Alaska Basin
- 12 Cherokee-Forest City Basin
- 13 Mid-Appalachian Basin



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Source: NETL

Williston Basin CORE-CM Project Team

UND Energy & Environmental Research Center
UND Institute for Energy Studies
UND Nistler College of Business & Public Administration
Pacific Northwest National Laboratory
North Dakota State University
Montana Tech University
Critical Materials Institute (Ames)
Basin Electric Cooperative
BNI Energy
Current Lighting Solutions
General Atomics
Illinois Geological Survey CORE-CM Team
Lignite Energy Council
Minnkota Power Cooperative

NDIC Lignite Research Program
North American Coal
North Dakota Department of Commerce
North Dakota Geological Survey
North Dakota Governor's Office
Northrup Grumman
Semplastics
South Dakota Geological Survey
U.S. Geological Survey
University of Alaska CORE-CM Team
University of Utah CORE-CM Team
Western Dakota Energy Association
Wyoming School of Energy Resources CORE-CM Team

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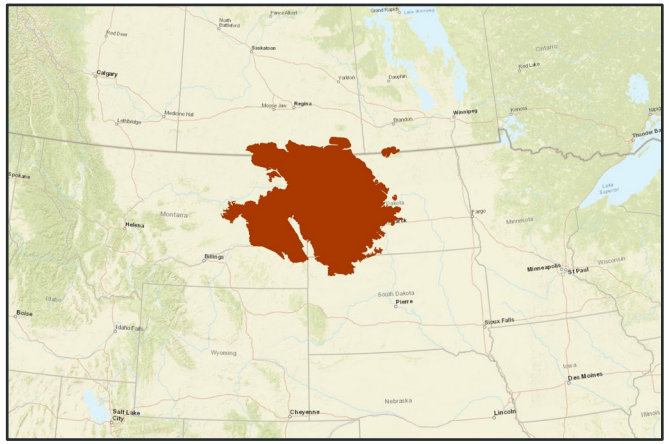
Critical Minerals – Why All the Hype?



Vital roles in our modern economy and national security.

Imported commodities that are vulnerable to supply chain disruptions.

Found in Williston Basin lignite and waste streams.

Williston Basin has potential to become a regional hub.

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Critical & Rare Earth Elements Symposium

for the Williston Basin

CORE-CM Williston Basin

EERC University of North Dakota

Join Us in Bismarck!

Free admission.

Scan the QR code to register.
This event will not be recorded!

Opening Reception
Monday, October 10, 2022
5:30–7:30 p.m.
Northern Lights Atrium
North Dakota Heritage Center

Keynote Speaker
President Andrew Armacost
University of North Dakota

Topic
The Initiative's importance to North Dakota and the Department of Defense

Symposium
Tuesday, October 11, 2022
10:00 a.m. – 3:00 p.m.
Bavendick Stateroom
National Energy Center of Excellence

Keynote Speaker
Commissioner Randy Christmann
North Dakota Public Service Commission

Topic
Bolstering the region's economic future with lignite resources

Questions?

John P. Kay
Principal Engineer
Emissions and Carbon Capture
jkay@undeerc.org
701.777.4580 (phone)

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)

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